ARCTEQ®
PART OF ENSTO GROUP

AQ-T3xx

Transformer protection device

Instruction manual

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Disclaimer

Please read these instructions carefully before using the equipment or taking any other actions with respect to the equipment. Only trained and qualified persons are allowed to perform installation, operation, service or maintenance of the equipment. Such qualified persons have the responsibility to take all appropriate measures, including e.g. use of authentication, encryption, anti-virus programs, safe switching programs etc. necessary to ensure a safe and secure environment and usability of the equipment. The warranty granted to the equipment remains in force only provided that the instructions contained in this document have been strictly complied with.

Nothing contained in this document shall increase the liability or extend the warranty obligations of the manufacturer Arcteq Relays Ltd. The manufacturer expressly disclaims any and all liability for any damages and/or losses caused due to a failure to comply with the instructions contained herein or caused by persons who do not fulfil the aforementioned requirements. Furthermore, the manufacturer shall not be liable for possible errors in this document.

Please note that you must always comply with applicable local legislation and regulations. The manufacturer gives no warranties that the content of this document is in all respects in line with local laws and regulations and assumes no liability for such possible deviations.

You are advised to notify the manufacturer in case you become aware of any errors in this document or of defects in the equipment.

The manufacturer reserves the right to update or amend this document at any time.

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1 Document information

Table. 1 - 1. History of Revision 1.

Revision	1.00
Date	November 2010
Changes	• The first revision of the manual.
Revision	**1.01**
Date	January 2011
Changes	• HW construction and application drawing revised.
Revision	**1.02**
Date	February 2011
Changes	• AVR chapter added. • Synchrocheck chapter revised. • Voltage measurement module revised. • Description for the CPU module added. • Description for the binary input module revised. • IRIG-B information added. • Ordering information and type designation updated. • Technical data revised.
Revision	**1.03**
Date	July 2012
Changes	• Second REF (restricted earth fault) stage added. • Volts-per-hertz protection function added. • Frequency specifications updated.
Revision	**1.04**
Date	January 2014
Changes	• Milliampere input module (optional) added. • The setting example added to the end of the differential function's description.
Revision	**1.05**
Date	February 2015
Changes	• Current and voltage measurement descriptions revised.
Revision	**1.06**
Date	March 2015

Changes	• Description for the trip logic revised. • Parameters of the differential protection function revised. • The "Connection examples" subchapter added to the "Measurements" main chapter. • Description for the line measurement added. • Description for the common function added.
Revision	1.07
Date	December 2019
Changes	• The "Construction and installation" chapter updated.

Table. 1 - 2. History of Revision 2.

Revision	2.00
Date	February 2023
Changes	• Updated the Arcteq logo on the cover. • An overall visual update for the manual's layout and design. • Added the "Safety information" chapter. • Added the previously separate documents "AQ 300 Operator's manual" and "AQ 300 Web server description" into the "IED user interface" chapter. • Various images updated. • Updated contact and reference information.

2 Safety information

This document contains important instructions that should be saved for future use. Read the document carefully before installing, operating, servicing, or maintaining this equipment. Please read and follow all the instructions carefully to prevent accidents, injury and damage to property.

Additionally, this document contains four (4) types of special messages to call the reader's attention to useful information as follows:

NOTICE!
"Notice" messages indicate relevant factors and conditions to the the concept discussed in the text, as well as to other relevant advice.

CAUTION!
"Caution" messages indicate a potentially hazardous situation which, if not avoided, **could** result in minor or moderate personal injury, in equipment/property damage, or software corruption.

WARNING!
"Warning" messages indicate a potentially hazardous situation which, if not avoided, **could** result in death or serious personal injury as well as serious damage to equipment/property.

DANGER!
"Danger" messages indicate an imminently hazardous situation which, if not avoided, **will** result in death or serious personal injury.

These symbols are added throughout the document to ensure all users' personal safety and to avoid unintentional damage to the equipment or connected devices.

Please note that although these warnings relate to direct damage to personnel and/or equipment, it should be understood that operating damaged equipment may also lead to further, indirect damage to personnel and/or equipment. Therefore, we expect any user to fully comply with these special messages.

3 Abbreviations

AC
: alternating current

AVR
: automatic voltage regulator

CB
: circuit breaker

CBFP
: circuit breaker failure protection

CPU
: central processing unit

CT
: current transformer

CTS
: current transformer supervision

CVT
: capacitive voltage transformer

DC
: direct current

DI
: digital input(s)

DLD
: dead line detection

DO
: digital output(s)

EFT
: electronic fast transients

EMC
: electromagnetic compatibility

EOB
: Ethernet Overboard

ESD
: electrostatic discharge

HMI
: human—machine interface

IDMT
: inverse definite minimum time

IED
: intelligent electronic device

IO
: inputs and outputs

LCD
: liquid-crystal display

LED
: light-emitting diode

NC
: normally closed

NO
: normally open

NTP
: Network Time Protocol

RF
: radio frequency

RCA
: relay characteristic angle

RMS
: root mean square

SCADA
: supervisory control and data acquisition

SDRAM
: synchronous dynamic random access memory

SLD
: single-line diagram

SOTF
: switch-on-to-fault

TMS
: time multiplier setting

VT
: voltage transformer

VTS
: voltage transformer supervision

4 General

The AQ-T3xx transformer protection IEDs are members of the AQ-300 product line. The AQ-300 protection product line in respect of hardware and software is a modular device. The hardware modules are assembled and configured according to the application IO requirements and the software determines the available functions. This manual describes the specific application of the AQ-T3xx transformer protection IEDs.

Arcteq protection IED can be ordered in two mechanical sizes. The AQ-T35x comes in half of 19 inch rack arrangement and the AQ-T39x comes in full 19 inch rack arrangement allowing for larger quantity of IO cards. The functionality is the same in both units.

5 IED user interface

5.1 Front panel

The figure below presents the front panel structure for AQ-300 series units, while the table below the image describes the functions of the front panel's various elements.

Figure. 5.1 - 1. AQ-300 front panel structure.

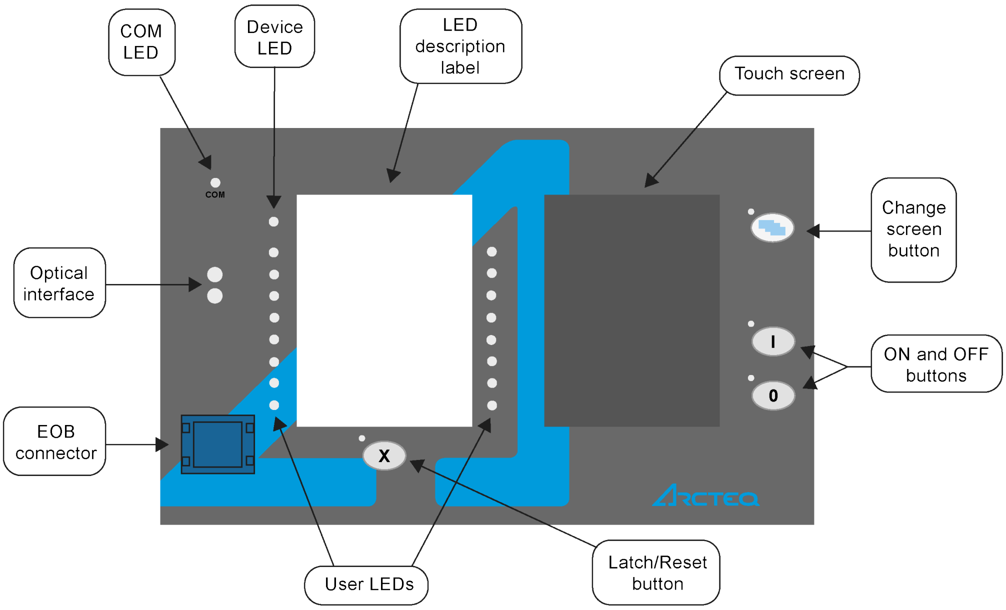


Table. 5.1 - 3. Elements of the front panel.

Function	Description
Device LED	One (1) three-colored circular LED. • Green = normal operation • Yellow = warning state • Red = alarm state
COM LED	One (1) yellow circular LED, which indicates the EOB communication link and activity.
User LEDs	Three-colored circular LEDs. Their number depends on the relay model.
LED description label	A changable label with LED functionality descriptions.
Optical interface	(for factory usage)
EOB connector	Ethernet Overboard communication interface. It attains an isolated and non-galvanic Ethernet connection with the help of a magnetic EOB device. The EOB device has an RJ-45 type connector which supports 10Base-T Ethernet connection to the user's computer.
Touch screen	The main screen, a 3.5" (320 x 240 pixels) portrait-oriented TFT display with a resistive touch screen interface. Optionally, the touch screen can be 5.7" and landscape-oriented.

Function	Description
Operation buttons	The device has four (4) capacitive operational buttons: • "X" (below the LED label) latches and resets the LEDs. • The button with a blue icon (top right) changes the touch screen menus. • "ON" and "OFF" (bottom right). Pushing a button causes an audible buzzer pressure feedback. All four buttons also have an LED off their top-left corner to indicate their status.

5.2 LED assignment

On the front panel of the device there is user LEDs with the "Changeable LED description label". Some LEDs are factory assigned, some are free to be defined by the user. Table below shows the LED assignment of the AQ-T3x2 and AQ-T3x3 factory configuration.

Table. 5.2 - 4. The LED assignment of AQ-T3x2 and AQ-T3x3.

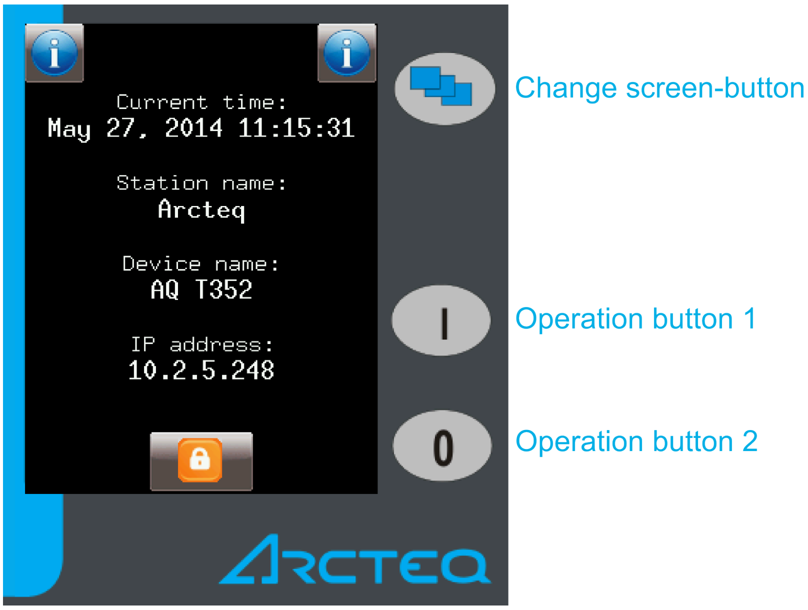
LED	Explanation
Gen. Trip	Trip command generated by the TRC94 function
OC trip	Trip command generated by the phase overcurrent function
OCN trip	Trip command generated by the residual overcurrent protection function
Therm. Trip	Trip command of the line thermal protection function
Unbal. Trip	Trip command of the current unbalance protection function
Inrush	Inrush current detected
Voltage trip	Trip command generated by the voltage-related functions
Frequ trip	Trip command generated by the frequency-related functions
REC blocked	Blocked state of the automatic reclosing function
Reclose	Reclose command of the automatic reclosing function
Final trip	Final trip command at the end of the automatic reclosing cycles
LED 312	Free LED
LED 313	Free LED
LED 314	Free LED
LED 315	Free LED
LED 316	Free LED

5.3 Touch screen

The touch screen comes with a variety of powerful features, including the ability to make customized menus. It also supports single-line diagrams (SLD). The touch screen can be accessed and controlled remotely via the device's web interface. For more information on the remote user interface, please refer to "The embedded web server" chapter below.

The image below depicts the main screen of the front panel as well as the "ON", "OFF" and "Change screen" buttons.

Figure. 5.3 - 2. The main menu and three operation buttons.



The touch screen is the main control where you can enable functions and input values.

The "Change screen" button changes the menu shown on the main display. The menus are in the following order by default: the main menu, the parameter menu, the online measurement menu, the events menu, and the system settings menu. You can also add a number of customized menus which can be created with EuroCAP software. Pushing the button moves the displayed menu by one, in a cycle.

The operation buttons can be used to define certain functions on customer-defined menus. For example, you can set up these buttons to turn a circuit breaker on or off, or to increment and decrement the position of a transformer's tap changer. For more information, please refer to the "Custom user-defined menus" chapter.

Main menu

The main menu is the first one shown when the device is turned on. It displays general information such as the device and station names, the current time, and language options (when available).

Figure. 5.3 - 3. Lock status indicator, as displayed in the main menu.

The lock status indicator shows whether a password is required to unlock the device before parameters or settings can be changed. By default, the device is not password-protected. However, is such a functionality is needed, you can set the password application via the web interface.

NOTICE!
The password cannot be set with the touch screen.

When a device is protected by a password, push the lock icon. This brings up a password input screen (see the image below) where you can enter the password. When the password is entered correctly, the lock status indicator on the main menu becomes unlocked, as does the menu in question. The device can be unlocked from any of the menus.

Figure. 5.3 - 4. The password input screen.

NOTICE!
The lock icon is displayed even when the device has no password!

Parameter menu

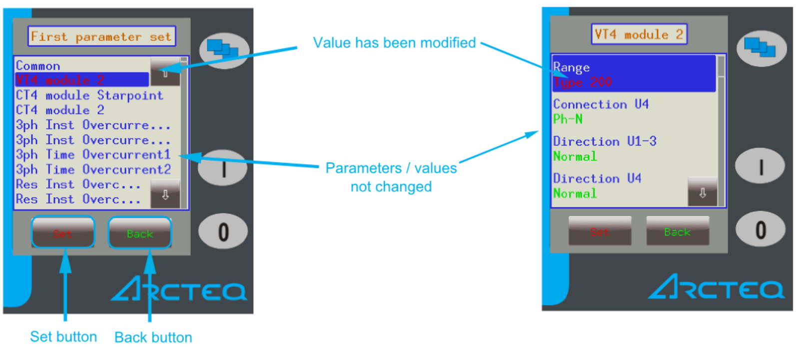
In the parameters menu (below) you can view, set and edit certain parameters within the device. You can also choose which of the parameter sets the device uses.

The parameter set that is currently active has a red box around it (see the figure below). When you want to edit or activate a parameter set, touching its name to select and highlight it and then press the "Edit" or "Activate" button.

Figure. 5.3 - 5. The parameter set menu.

The Activate button activated the selected parameter set, which the device will now use. Depending on the device's configuration, the "Activate" button may not be available. The Edit button takes you to another screen where you can choose which function blocks the parameter set uses. Please note that when there is only one parameter set, the device takes you immediately to the parameter set edit screen (below).

Figure. 5.3 - 6. The parameter set edit screen (left) and the function block screen (right).



Normally, the various function blocks appear blue. However, if any value has been changed within a function block, its listing appears red to notify the user. This also happens in the function block screen, where unmodified parameter values appear green but modified values appear red.

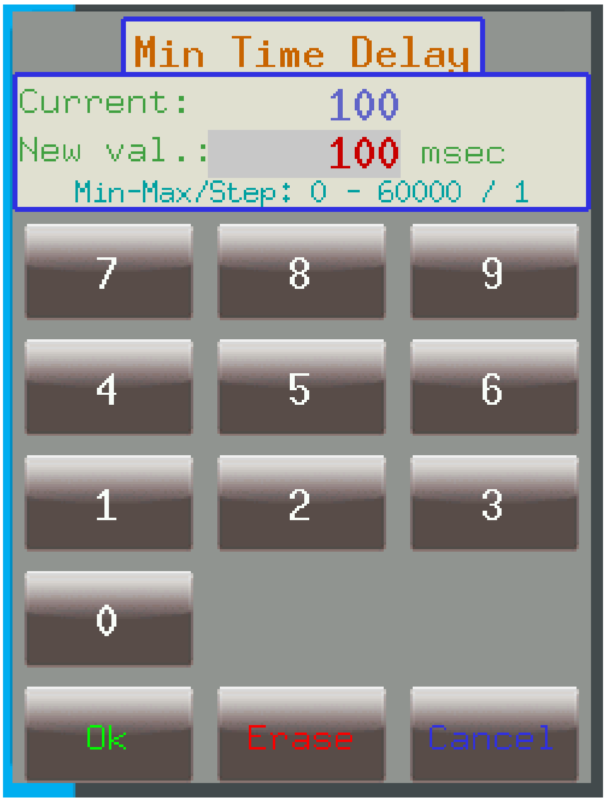
The Set button brings up a screen where you can modify a value. If there is a lock icon instead of the "Set" button, the device must first be unlocked. The Back button returns you to the previous screen.

Within all function blocks, the parameter values can have one of the following four types of input:

- Integer
  A whole number, entered with the number pad.

- Floating-point number
  A number with a decimal point, entered with the number pad. Please note that the pad has the decimal point available only when the value can be entered as a floating-point number!
- List item
  The parameter lists thr available options as a list, and the user selects the desired option from them.
- Checkbox
  The user can enable and disable the parameter as a whole.

Figure. 5.3 - 7. Editing the parameter values.



The new parameter value is put in the "New value" field. The "Current value" field shows the parameter value that is currently in use. The "Min–Max/Step" field shows the range within which the parameter's value can be modified, as well as the step with which the value can be incremented or decremented. For example, in the image above, the range is between 1 000 and 10 000 with a step value of 1. This means that the value can be 1 001, 1 002, 1 003,...,9 999, 10 0000. If the step value were 5, the field would only accept values such as 1 005, 1 010, 1 015, and so on.

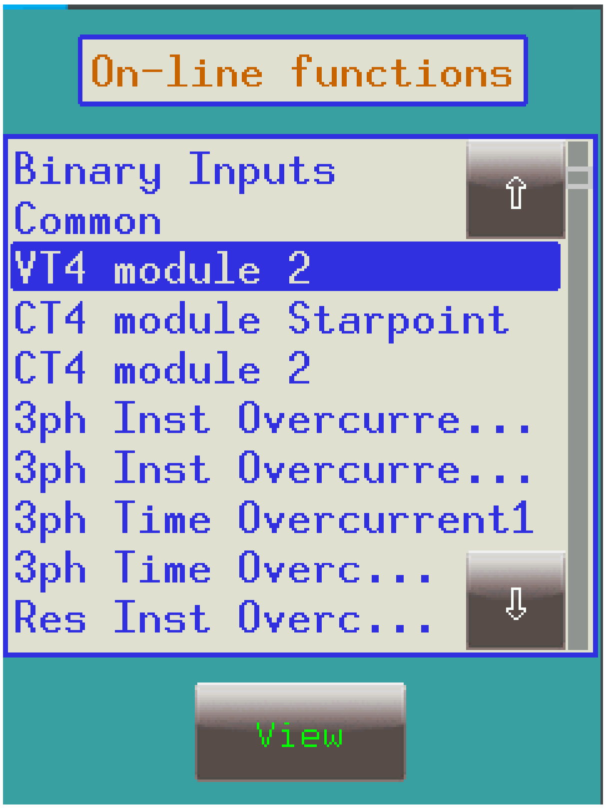
The OK button confirms the value in the "New value" field and returns the user to the previous screen. The Cancel button deletes a single digit from the "New value" field. The Erase button discards any changes to the current parameter and returns the user to the previous menu item.

CAUTION!
Make sure that only one person edits the parameters at any one time, either in the touch screen or in the web interface! Simultaneous editing leads to confusion as to what the values of a parameter set actually are.

Online measurement menu

The online measurement menu displays real-time data depending on what is connected to the device. When you have selected a specific function block from the online functions list, clicking the View button takes you to a new window that displays the parameters and their current values. The image below shows the values of VT4 module 2: the voltages and angles for channels U1 and U2.

Figure. 5.3 - 8. Online measurement menu.

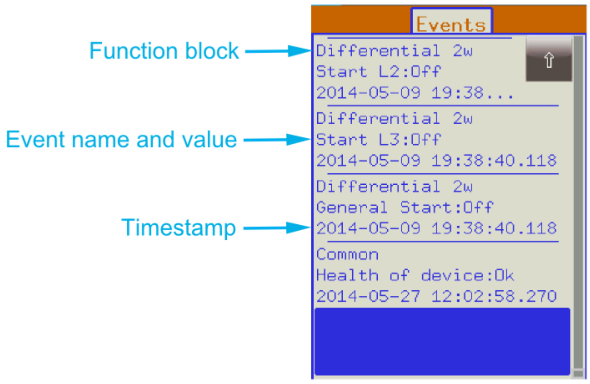


Events menu

The events menu displays a list of events that have occurred within and in relation to the device. This menu screen is continuously updated. If the scrollbar on the right is at the bottom, the screen shifts as a new event occurs. However, if the scrollbar is not on the bottom, the screen stays in place even when a new event occurs. This allows you to take a closer look at the events.

The first row of an event displays the function block's name, the second row displays the event's name and value, and the third row displays the event's time stamp (see the image below).

Figure. 5.3 - 9. Event structure.



NOTICE!
The events menu does not display the whole event log, only the first few hundred items in the log!

System settings menu

Figure. 5.3 - 10. System settings menu.

In the system settings menu you can set certain parameter values that are related to the device itself (as opposed to its protection functions and operations). The menu works similarly to the parameters menu and the same properties apply.

Table. 5.3 - 5. The system settings.

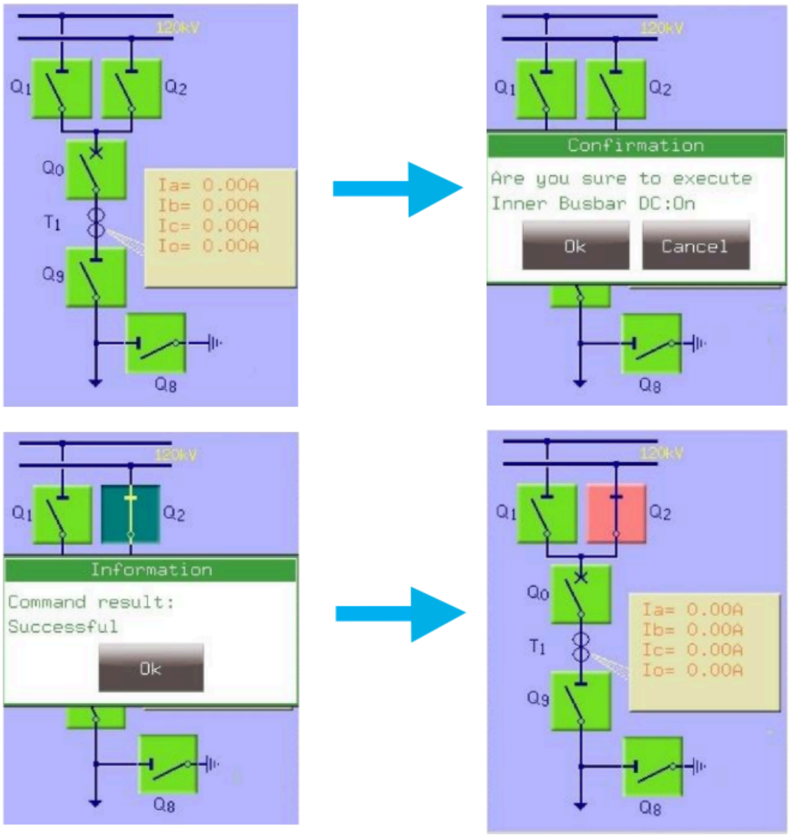
Setting	Description
System parameters and station bus settings (IP address, netmask, default gateway, DNS servers)	Please contact your local network administrator for further information about these settings.
Ethernet communication (IEC 61850 enabled, IEC 104 enabled)	Enables or disables the IEC 61850 and IEC 104 communication protocols.
Serial communication	Selects which serial protocol the device uses. The "Serial baudrate" field sets the baudrate to a specific amount. Please note that this and link address only apply to legacy protocols!
Time synchronization	When time synchronization via NTP server addresses is enabled, the device uses Network Time Protocol to synchronize time with one of the servers. The device also supports other, non-NTP time synchronization methods, such as pin and serial.
Time zone settings	"GMT offset" defines the positive or negative offset for Greenwich Mean Time. "Use DST" and "DST start/stop" define the daylight savings time setting. As DST is different in each country, set these as appropriate.
LCD backlight	Changes the brightness of the touch screen's back illumination.

Custom user-defined menus

You can add menus based on your application needs with the help of the AQtivate 300 software. You can also set up the operation buttons "I" and "0" to perform specific functions.

For example, let us say we have the following network depicted in the top-left image in the figure below as a single-line drawing. We have set the operation buttons to function as "ON" and "OFF", and now we would like to switch the line disconnecter Q2 on.

Figure. 5.3 - 11. Turning on Q2.



(1) First, we press Q2 on the touch screen to highlight the object. This causes Q2 to start blinking for a short while; if an action is not performed within this time, the object deselects on its own. So, while Q2 is highlighted and blinking, we press the "I" button (configured to function as an "ON" button) to turn it on. (2) A window pops up to confirm we want to do this action; again, we have a shirt time to give an answer (in this case, to press "Yes") before the requested operation is automatically cancelled. (3) Another window pops up to state that the operation was successful. (4) After acknowledging this window, the display is updated as appropriate, with the Q2 line disconnector in the "ON" position.

Just as the online measurement and events menus, this menu is also updated continuously. Therefore, any kind of change in the states or in the measured parameters are shown and updated accordingly. If there is an error with an operation, the device signals the user of this with an error pop-up window that includes the error code and the reason for the error.

5.4 The embedded web server

Introduction

This product offers the ability to remotely monitor and modify various parameters and settings within the device. You can access the front panel and choose other options with the help of a web browser. With the user-friendly interface, you can easily manage the device. Password protection is available to grant certain priviledges and access to special functions.

You can perform the following actions with the embedded web server:

- modify user parameters
- check the event list and disturbance records
- manage the password
- display the measured data and the generated binary information
- perform commands

- provide remote or local firmware updgrades
- perform administrative tasks.

System requirements

In order to access the device interface you need a compatible web browser as well as an Ethernet connection. It is recommended that the screen resolution is at least 1024 x 768 so that the screen can display data properly.

You can use any of the following web browsers:

- Microsoft Internet Explorer, version 7.0 or higher
- Mozilla Firefox, version 1.5 or higher (version 3.0 or higher recommended!)
- Apple Safari, version 2.0.4 or higher
- Google Chrome, version 1.0 or higher
- Opera, version 9.25 or higher

You must also enable JavaScript within your browser. For security reasons the device is only allowed a limited number of connections over the network.

To access the device via a web browser write the correct IP address on the browser's address bar. You can find the device's IP address on the main menu of the device's touch screen.

5.4.1 Ethernet connections

Properties of the Ethernet connection

An AQ-300 unit has five (5) Ethernet ports built into the device, allowing it to be connected to IP/Ethernet-based networks. The unit has the following Ethernet ports available (the first is located in the front panel, the others on the rear side of the CPU unit):

- Ethernet over board (EOB) 10Base-T user interface
- Station Bus (100Base-FX Ethernet)
- Redundant Station Bus (100Base-FX Ethernet)
- Process Bus (100Base-FX Ethernet, in preparation)
- 10/100Base-Tx port via the RJ45 connector

There are three different types of interfaces for the communication ports:

- The EOB interface is attachable to the device's front panel by a proprietary magnetic connector. The connector box ends in a RJ45 8/8 plug, and the interface is a 10Base-T full duplex interface.
- The 100Base-FX Ethernet interface is of type ST, which offers 1 300 nm/MM for a 50 μm/125 μm (or, 62.5 μm/125 μm) fiber.
- The 10/100Base-Tx Ethernet interface is an RJ45 8/8 plug.

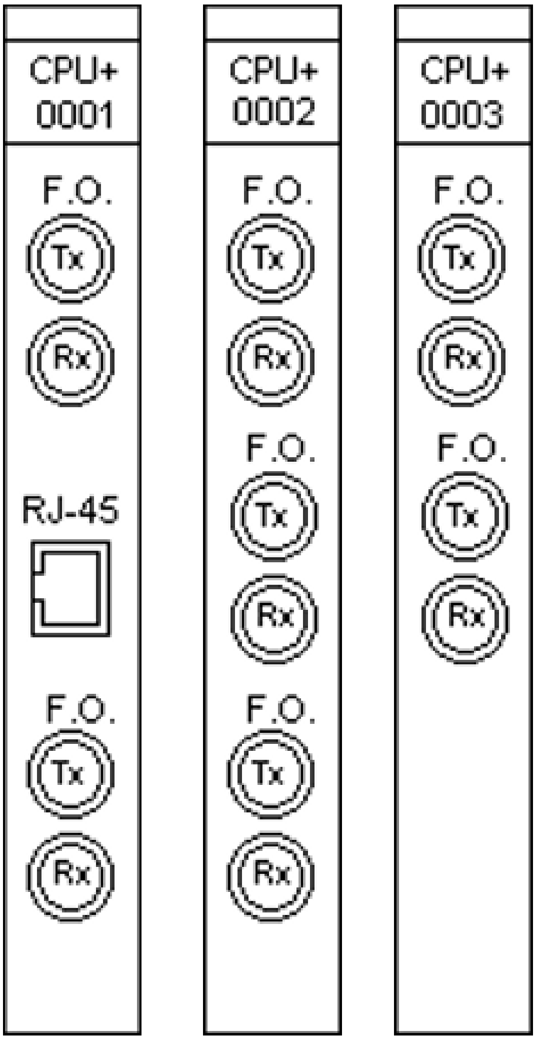
The following table catalogues the different Ethernet communication versions available for the different AQ-300 CPU versions.

Table. 5.4.1 - 6. The available Ethernet communication in different CPU versions.

CPU version	EOB	Station Bus	Redundant Station Bus	Process Bus	RJ45	Legacy port/protocol
CPU+0001	Yes	Yes	No	Prep	Yes	No
CPU+0002	Yes	Yes	Yes	Prep	No	No
CPU+0003	Yes	Yes	Yes	No	No	No

The diagram below depicts the three (3) different CPU versions and their structures:

Figure. 5.4.1 - 12. The three CPU versions.



Settings needed for Ethernet connection

The AQ-300 devices can only be accessed over Ethernet-based communication protocols. This is why it is very important for the network to be set up correctly before accessing the device.

IP settings

The device operates with fixed IPv4 addressing. At the moment dynamically assigned IP addresses are not supported. We recommend using the private address range as defined in RFC 1918. All addresses must be in the same network range. Additionally, the computer should be set to use fixed IP settings.

You can connect to a stand-alone device by plugging the EOB cable into your computer or by using the RJ45 connector at the back of the device (this requires a crossover UTP cable). When you want to connect the device to a station or corporate network, contact the system administrator for all the required information: an available IP address, the gateway address, the netmask, the DNS and NTP server addresses.

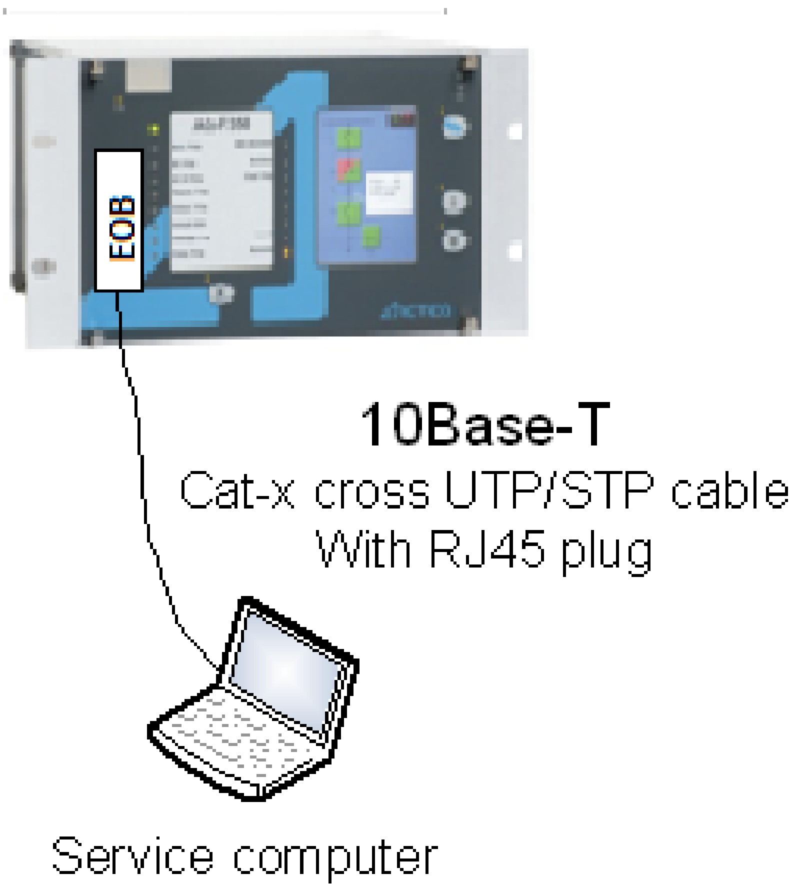
Web browser settings

Make sure that your browser does NOT use a proxy server while accessing an AQ-300 device. However, if there is a proxy server in your network, contact the system administrator and have them add an exception.

EOB connection

Attach the magnetic EOB connector to the front panel of the device; the magnets assure that the adapter is in the correct position. Next, connect the other end of the cable to a computer's RJ45 port (see the figure below).

Figure. 5.4.1 - 13. Using the EOB connection.

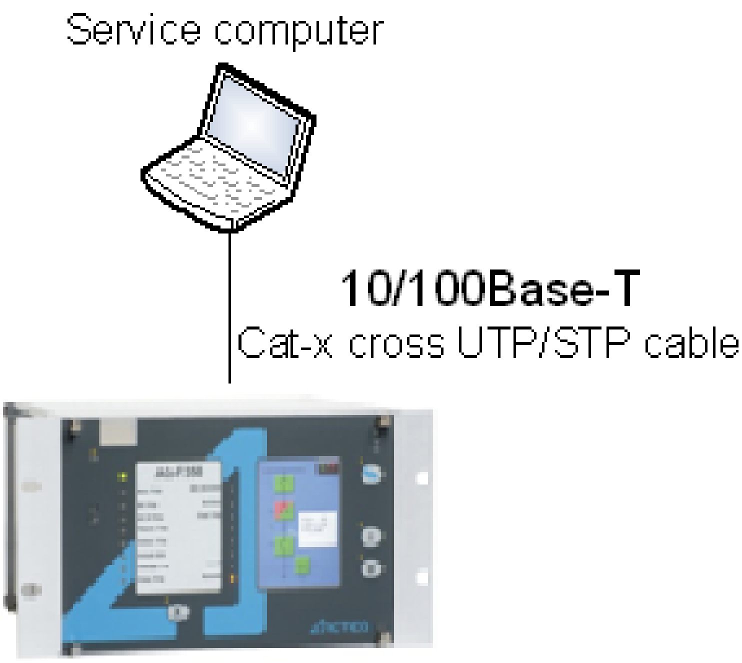


Please note that the RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

RJ45 connection

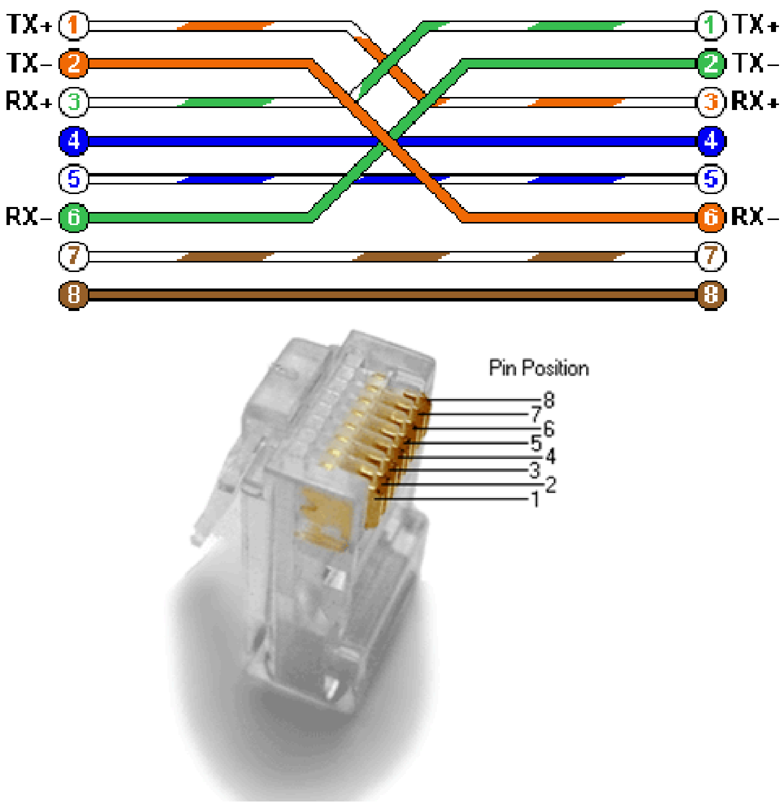
As seen in the beginning of this chapter, the CPU version "+0001" also has an integrated RJ4 port. When using a UTP crossover cable with RJ45 connectors at both ends, you can connect the device directly to a computer (see the figure below).

Figure. 5.4.1 - 14. Using the RJ45 connection.



The crossover cable's pinout has been depicted in the diagram below:

Figure. 5.4.1 - 15. The pinout of the crossover cable.

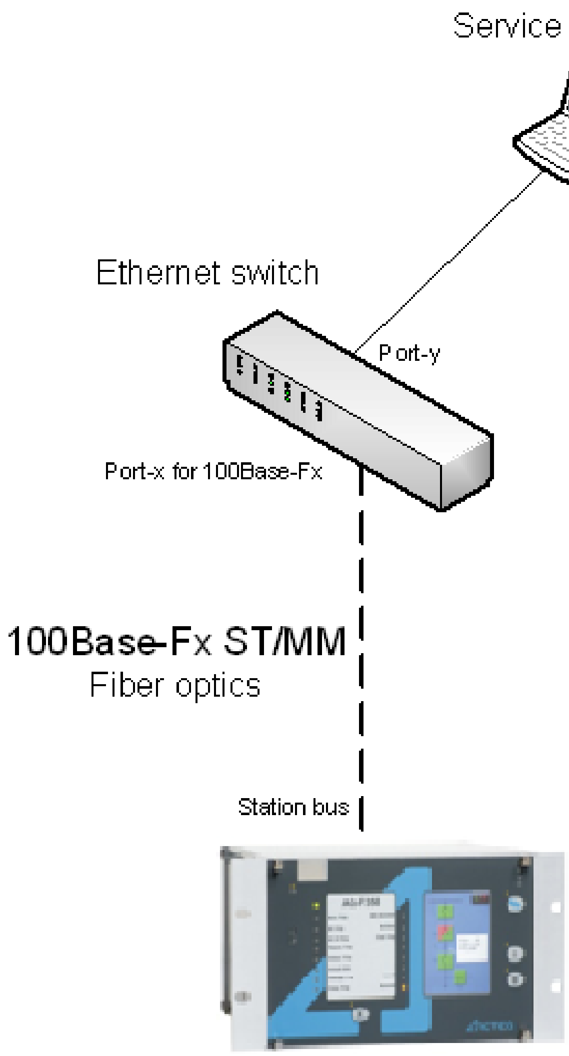


Please note that the cable's RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

ST-type fiber optic connection

The ST-type fiber optic connector of the 100Base-FX Ethernet provides a connection to an Ethernet switch with an identical fiber optic input. When using this connection, all the network's IEDs with client functionalities (e.g. a computer) have access to the device (see the figure below).

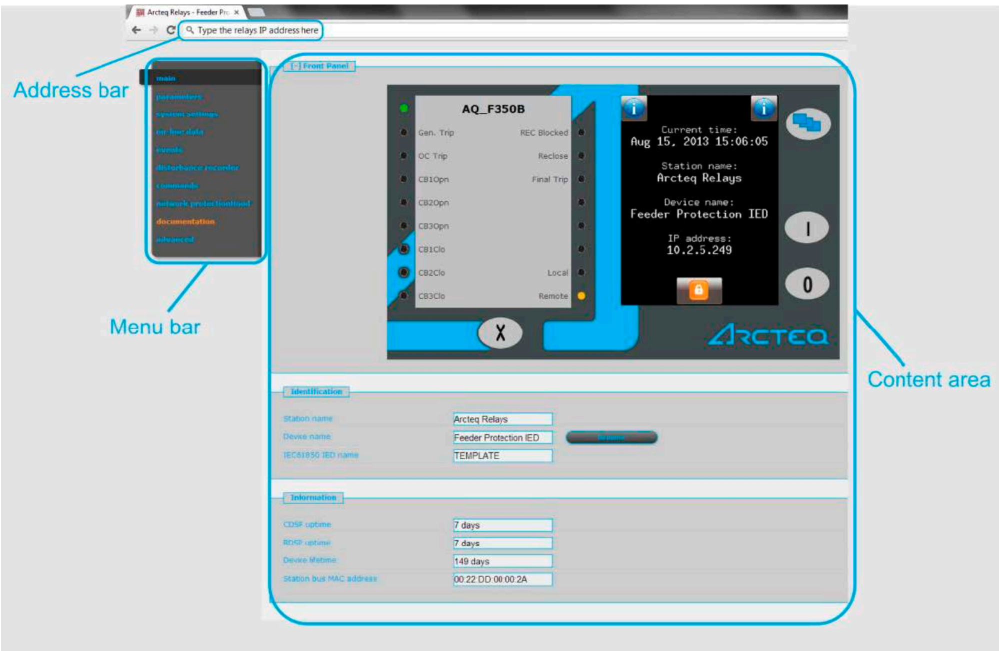
Figure. 5.4.1 - 16. Using the ST-type fiber optic connection to connect computers via an optical Ethernet switch.



5.4.2 Getting started

Make sure you are connected to your AQ-300 device and that you have JavaScript enabled within your web browser. Type the IP address of the device into your browser's address bar to access its embedded web server (see the image below).

Figure. 5.4.2 - 17. Web server elements.



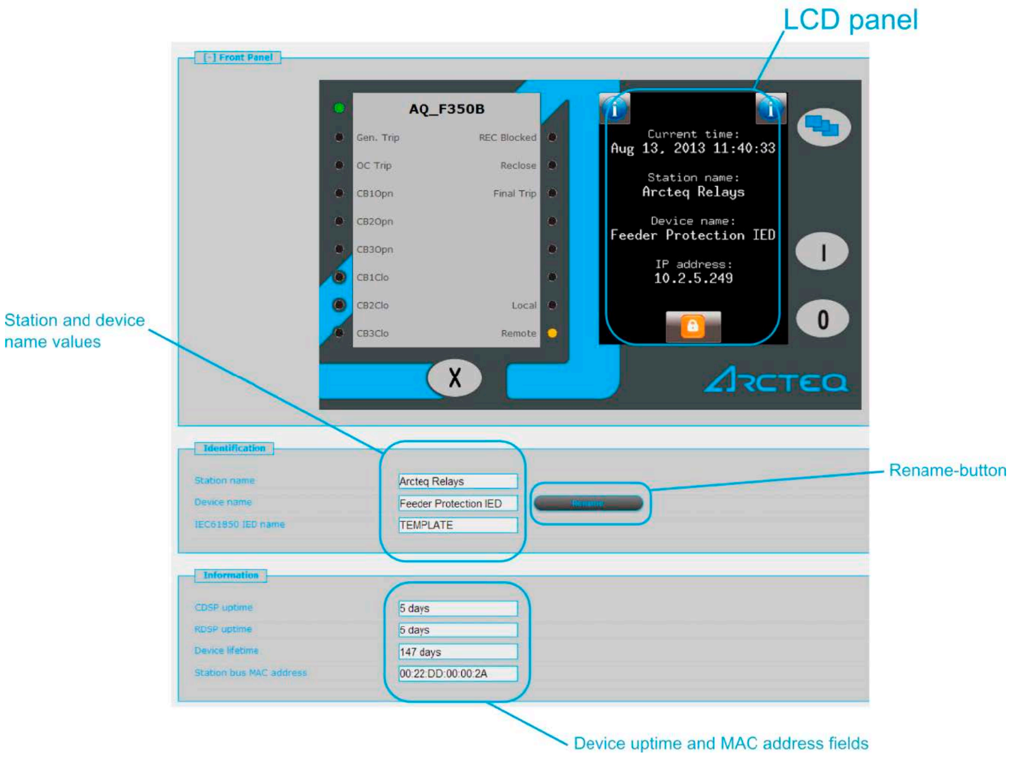
The menu that is currently selected is highlighted in black (in the image above, the main menu is selected). If the content area is too long to fit the browser window, you can scroll down; the menu bar will always be visible as it follows the user.

In some configurations the language that is currently displayed can be changed; to do this, click one of the other available languages represented by flags, located at the top of the touch screen. The page automatically refreshes in the chosen language. Please note that changing the display language only affects the local browser, NOT other browser or the language of the touch screen.

5.4.3 Menu items

Main menu

Figure. 5.4.3 - 18. The main menu and its elements.



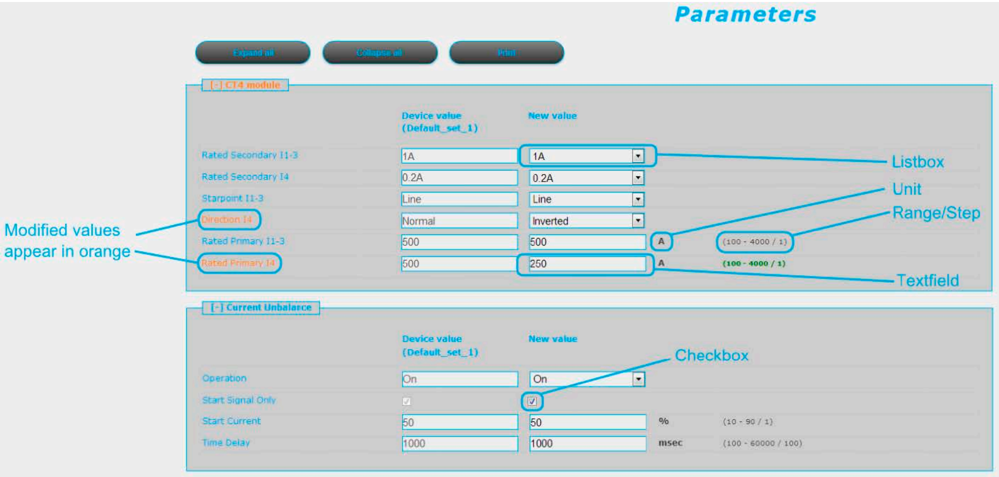
In the main menu you can control the device's front panel. The image of a touch screen (located on the right) behaves the same way as the actual touch screen. For more information on the touch screen, please refer to the "Touch screen" subchapter in the "IED user interface" main chapter.

In the "Identification" section of the view, you can change the station name and the device name. Type the desired name in the relevant field and click the Rename button.

The "Information" section shows additional information about the device. The uptime fields show how much time has passed since the device was last powered on. The "Station bus MAC address" displays the network card's MAC address, which is a uniwue identification number assigned by Arcteq (the address range assigned by the IEEE authority). Please note that these fields are read-only and cannot be modified!

Parameters menu

Figure. 5.4.3 - 19. The parameters menu and its elements.



You can view and change various parameters and variables in this menu. You can manage the different parameter sets by resetting, renaming, exporting and importing them. You can also apply a password for importing, exporting and setting.

All parameters are part of specific function blocks. You can expand and collapse the individual function block information boxes by clicking the [+] and [–] signs in front of its name. You can also use the button at the top to expand all function blocks, collapse them all, or print out a printer-friendly layout of the function blocks (opens in a new browser window).

The parameter sheet has the following general layout

- The first column contains the name of the parameter. In multilingual devices changing the language also changes this name.
- The second column displays the current values of the selected parameter set stored in the device. Changing the parameter does NOT activate it, it only loads to the fields.
- The third column is used to give parameters user-desired values. When changed, the color changes to blue to draw attention to the change. The expected value range and step are located to the right of the parameter line.

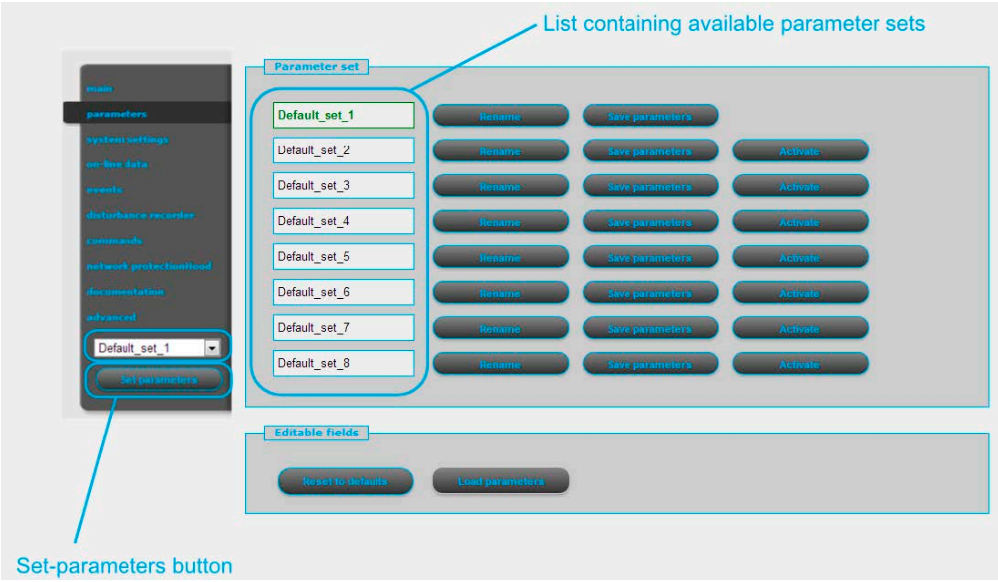
The parameter values are displayed in text fields, checkboxes, or listboxes. All of these can be modified; the name of the parameter whose value has been modifed appears in orange, as does the name of the function block (see the image above). When modifying *text fields*, please be mindful of the parameter range and step, although the device does alert the user when an improper value is entered. The new value is displayed in red. *Checkboxes* (Boolean parameter type) enable and disable certain functions and properties; a ticked checkbox means that the parameter is enabled. *Listboxes* (enumerated parameter type)open a drop-down menu with a number of predetermined values. When a value that is not the default is selected, both the letters and the box outline become red.

> **NOTICE!**
> A parameter line has the unit between the new value textfield and the range/step information when applicable. Some parameters do <u>not</u> have units!

The parameter values are checked for changes when you navigate away from the parameter page or when you try to load another parameter set. A pop-up window notifies you if you have made changes and try to leave the page without saving them. Clicking Cancel returns you to the parameter page, whereas clicking OK ignores the changes.

In the "Parameter set" section of the page there are options for managing the parameter sets. The section lists all the available parameter sets, and each can be manipulated with the buttons located on the right of the line.

Figure. 5.4.3 - 20. Managing multiple parameter sets.



With the **Activate** button, you can enable the selected parameter set. The device will now use the values from this set. The **Rename** button, unsurprisingly, renames the selected parameter set. The names can include alphanumeric characters, spaces, dashes and underscores. Please note that two or more parameter sets CANNOT share the same name! The **Save parameters** button saves the selected parameter set in a separate file, which can be loaded into the device at any time.

The **Set parameters** button (located below the menu bar on the left) overwrites the selected parameter set with the values that are on the screen. Note that this only modifies the values of the selected set; to have the device use these values you must also activate the set! You can also set a password that is required before overwriting can be done.

The "Editable fields" section has two buttons. The **Reset to defaults** button replaces the values on the screen with the factory default settings. With the **Load parameters** button you can import values from a parameter set file. These values must be saved after loading by pressing the **Set parameters** button.

> NOTICE!
> These buttons and functions only appear if the device is configured to have more than one parameter set. The available buttons and functions depend on the configuration.

System settings menu

In the system settings menu you can adjust the miscellaneous device settings. This menu can also be password protected. The text fields, checkboxes and listboxes function the same as in the parameter menu. The column structure is also the same.

The **Set settings** button (located below the menu bar on the left) enabled the device to use the values displayed on the screen at the time the button was clicked. Please note that if the device's IP address has changed, the device must first be accessed through the new IP address.

Figure. 5.4.3 - 21. The system settings menu.

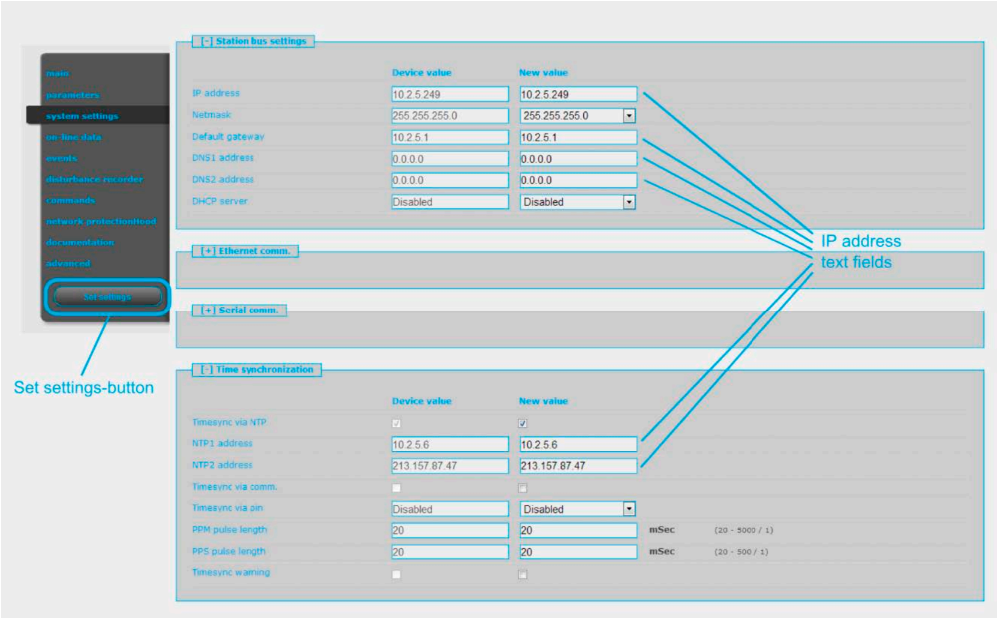


Table. 5.4.3 - 7. The system setting sections and their content.

Section name	Description
Safe settings	If enabled, the device asks you to confirm the saving of new settings by pressing the "I" (ON) button on the device's front panel. Pressing "0" (OFF) discards the changes. This selection must be made within 300 seconds.
Power system frequency	Sets the power system frequency. By default it is 50 Hz, can be changed to 60 Hz. **CAUTION!** Changing this parameter initiates a system restart!
Station bus settings	Contains the settings for IPv4-based communication (IP address, mask, gateway, DNS address). The DHCP server function can be switched on with a combo-box. **CAUTION!** Uncontrolled use of the DHCP server function can cause serious communication failures!
Ethernet communication	The device can communicate using several Ethernet-based protocols at the same time. Only IEC 61850 is licensed, other protocols are available by default. You can adjust the T0 time of GOOSE messaging with the GOOSE repeat rate combo-box.
Serial communication	Contains the physical parameters for serial communication (only one protocol can be selected!). Note that serial communication requires a proper CPU card!
Time synchronization	Contains the settings for a broad range of time synchronzation protocols (NTP, serial communication, pulse inputs). If the "Time sync warning" parameter is enabled and the device is not synchronized, an alarm is raised (that is, the "Status" LED becomes yellow).
Time zone settings	Contains the settings to offset GMT and to define daylight savings time.

Section name	Description
LCD backlight	Contain the parameters to control the LCD panel's behaviour. The light switches off after its set timeout. The "Backlight group" parameter is useful when you have two or more devices close to each other: touching one switches on all devices that have been configured to belong to the same group.

Online data menu

Figure. 5.4.3 - 22. The online data menu.

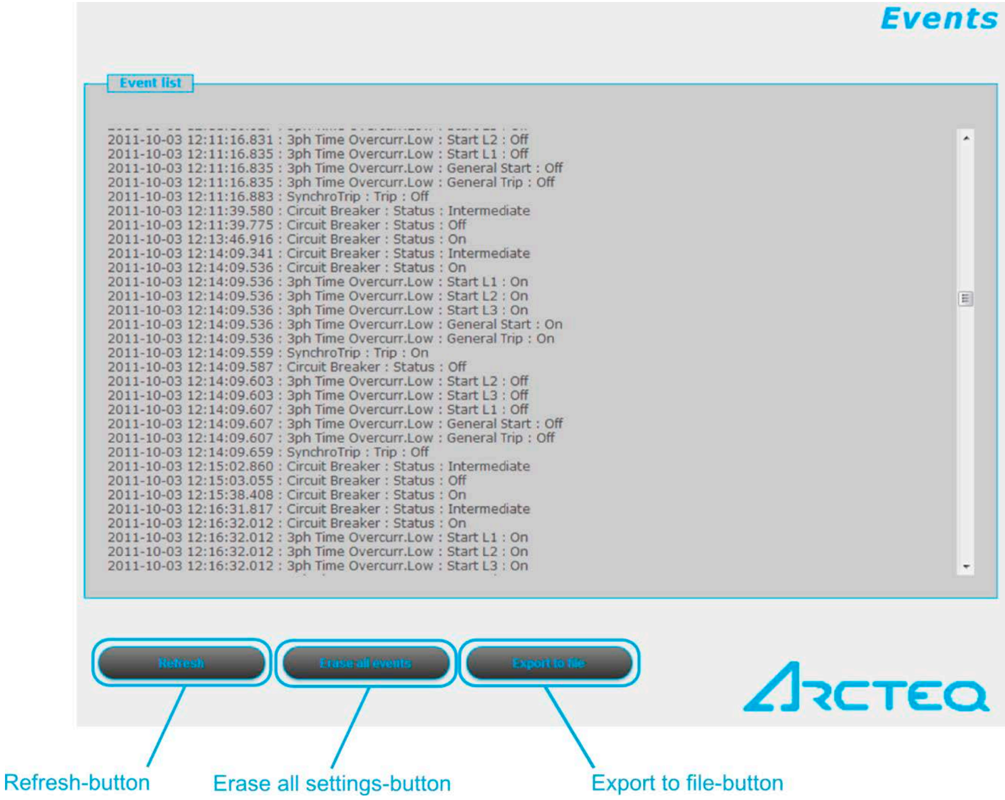
This menu displays the data measured by the device. Each block has their own section, and these sections can be expanded and collapsed individually as needed with the [+] and [–] signs in front of their names. The values on screen are updated every second, which may cause older systems to slow down or halt the browser altogether. All data is strictly read-only, and cannot be modified. If there is a counter on the page, next to it will be a button that resets it.

Binary data is displayed as a checkbox (for example, the "SystemWarning" parameter in the first section in the image above), whereas enumerated data is presented as text information. If you are using a browser compatible with HTML5, analogue measurements are drawn as vectors.

Events menu

This page displays the events that have occured in the device. The events are listed in the following format: [local time] : [function block] : [channel] : [new value].

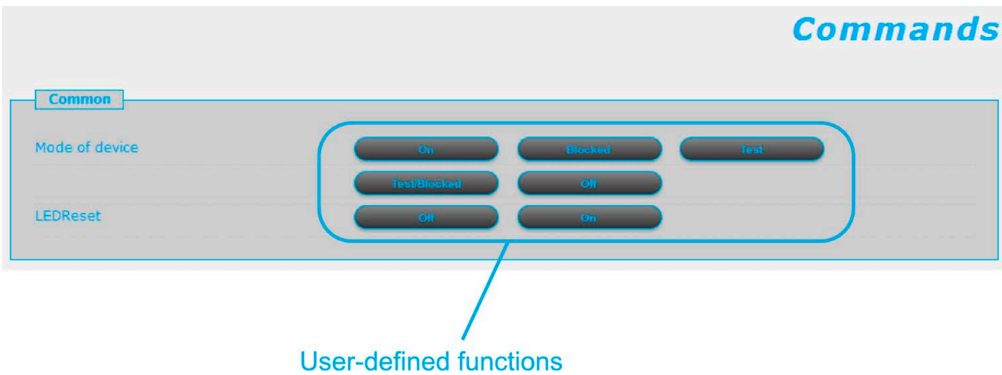
Figure. 5.4.3 - 23. Elements of the events menu.



With the **Refresh** button you can refresh the list displaying the events, the **Erase all events** button clears the list on the screen, and the **Export to file** button downloads the events and saves them as a .txt file.

Commands menu

Figure. 5.4.3 - 24. The commands menu.

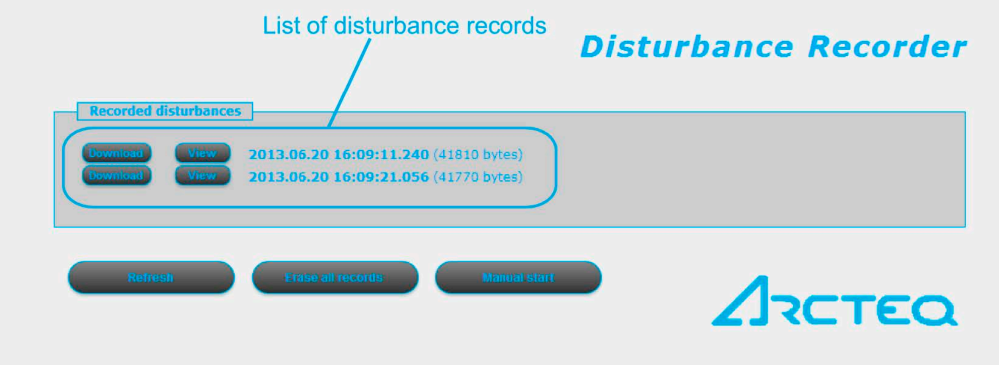


In the commands menu you can instruct the processor to carry out customized, user-defined commands. You can use the various mode buttons (**On**, **Blocked**, **Test**, **Test/Blocked**, **Off**) and LED buttons (**On**, **Off**) to define functions. A status update is always generated with a command, regardless of whether the command was successful or not. If the command was unsuccessful, the device gives the reason for the error.

Disturbance recorder

This page displays a list of the disturbance records that the device has recorded.

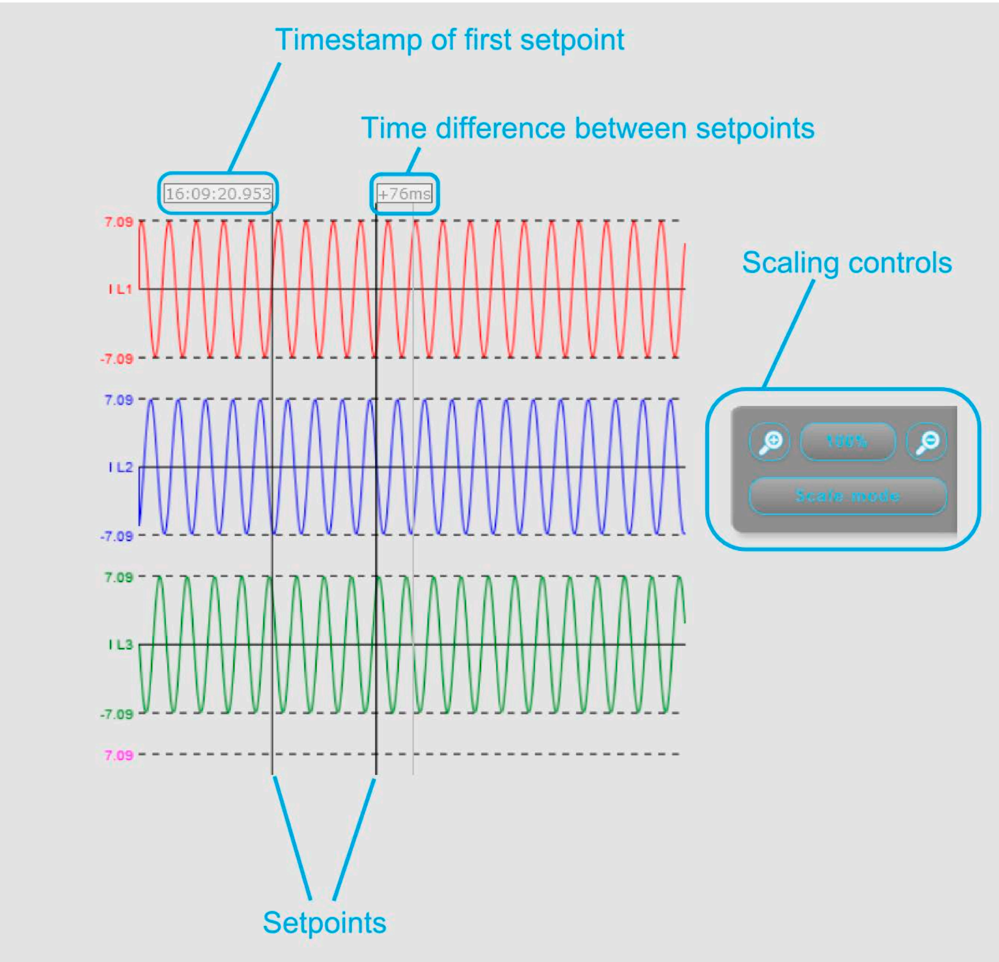
Figure. 5.4.3 - 25. Disturbance recorder.



The "Recorded disturbances" section lists all disturbance records. You can refresh the list with the Refresh button to display any new disturbance records that have occurred after the page was opened or refreshed last. You can also clear the list with the Erase all records button. Additionally, you can create a disturbance record manually by clicking the Manual start button.

There is one one record per line. You can download the chosen record by clicking the Download button on its line; the device downloads you a COMTRADE file which you can then open with any supporting software for further evaluation. You can also click the View button to open a new browser window which then displays a simple preview of the disturbance record (see the image below).

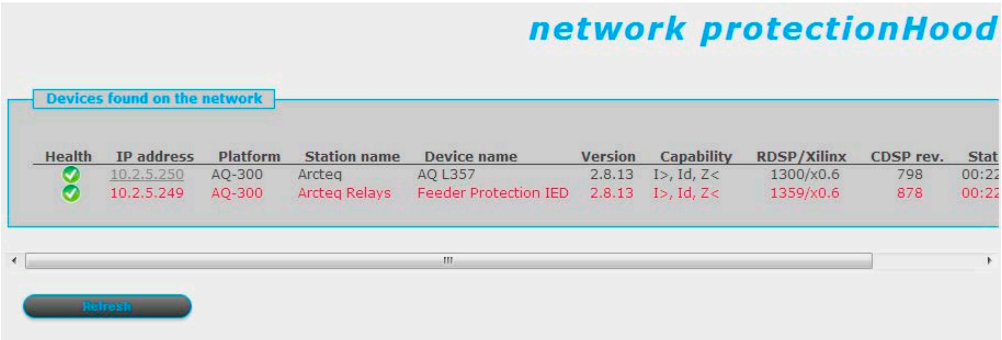
Figure. 5.4.3 - 26. Example of a disturbance record preview.



You can set a setpoint by clicking anywhere on the graph, and the positioning the cursor to a desired second point. The preview then displays the timestamp of the first setpoint, and the time difference between the two setpoints. You can also scale the time axis with the scaling controls (the plus and minus magnifying glasses), or by clicking the Scale mode button to switch between standard and scaled modes. The scaled mode stretches the Y axis of all recorded values.

Network protectionHood

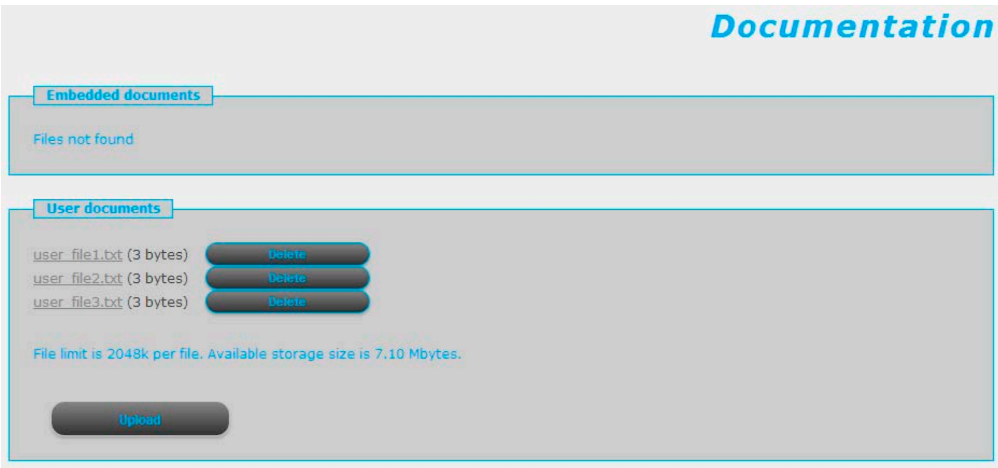
Figure. 5.4.3 - 27. The network protectionHood menu.



This page shows all other devices that are located in the same network with the AQ-300 unit. The page identifies compatible devices and displays information about them, such as their IP address and version. The device that is currently accessed is highlighted in red in the list. You are redirected to other devices by clicking their corresponding links. The Refresh button scans the network for connected devices.

Documentation

Figure. 5.4.3 - 28. The documentation menu.

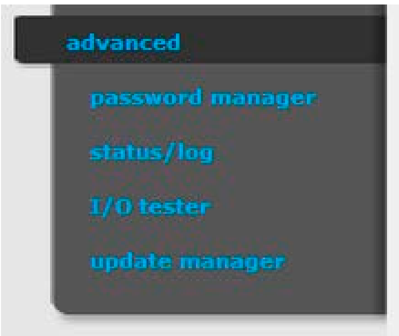


This page displays the documentation files on the device. You can upload other documents and files on the device, which are then saved and can be accessed later. One file can be up to 2048K , and there is storage for up to 8 MB of documentation.

The "Embedded documentation" section displays all the documents that have been preloaded into the device. You cannot delete these. The "User documents" section lists all the files the user has uploaded into the device, and you can delete them with the Delete button. You can upload a selected file with the Upload button. Please ensure that the file size is below the limit and that you have enough storage left before commencing the upload.

Advanced

Figure. 5.4.3 - 29. The Advanced menu.

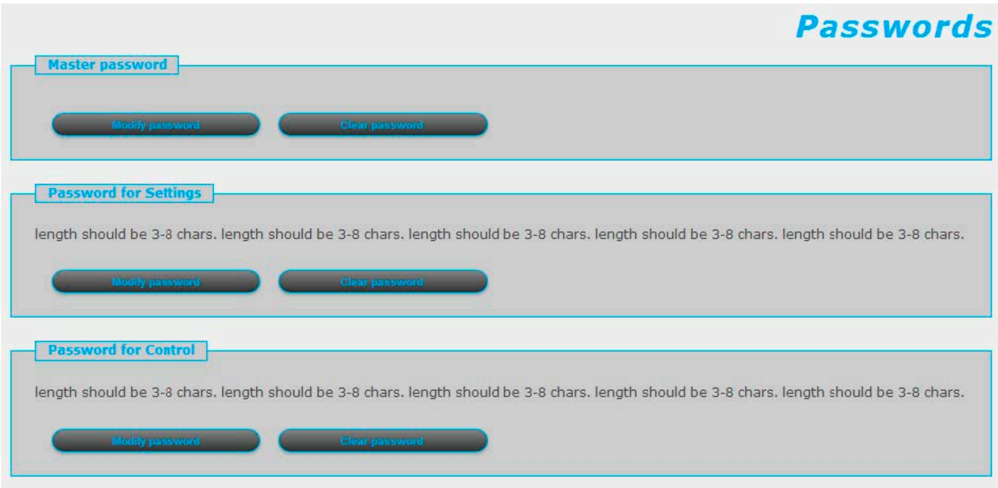


This menu displays the additional, more advanced options. You can set a password request before a user is allowed access to these options.

Password manager

You can modify and clear the three available passwords. The *master password* is used for accessing the Advanced menu. The *password for settings* is required when a user wants to set parameters or settings, or wants to clear counters in the Online data menu. The *password for control* is required when executing commands in the Commands menu. If no password has been created, you can create one with the Modify password button.

Figure. 5.4.3 - 30. Password manager.



Status/log

The Status/log submenu displays information from various logs. The log files are primarily meant for the manufacturer, but a user can also view them.

Figure. 5.4.3 - 31. Status/log.

The **Get report** button generates a .zip file that has all of the log files archived together. The files have valuable information and they can help in analyzing errors and malfunctions; see the table below for the different log types and their contents.

Table. 5.4.3 - 8. Log types.

Log name	Description
Relay CPU	Displays the logged events that are connected to the relay's CPU.
SPORT	Displays the log file from the SPORT communication interface.
System startup	Displays the events that have occurred when the system was started up.
Serial Comm	Displays the log file from the serial communication interface.
LCD display	Displays the log file about the events that have occurred with the LCD display.
IEC 61850	Displays the log file from the IEC 61850 communication interface.
Access	Displays information about the users who have accessed the device remotely through the embedded web browser interface.
Error	Displays the errors that have occurred with the remote user interface.

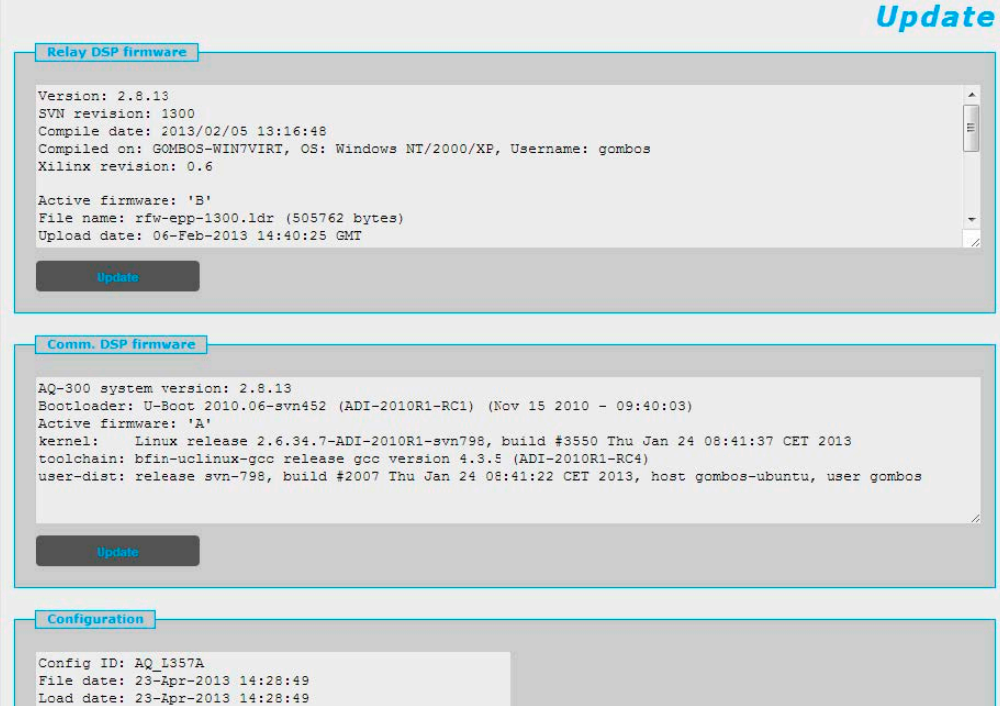
NOTICE!
All log files are in English, regardless of your language selection!

Update manager

When a new version of the firmware is available, it can be updated in this submenu. Click the **Update** button of the correct section to select the new firmware file and upload it into the device. Please make sure that you are updating the right firmware; for example, do not attempt to update the "Relay DSP firmware" section with a "Comm. DSP firmware" file!

This page also displays information about the firmware currently in use as well as of the configuration of the device.

Figure. 5.4.3 - 32. Update manager.



5.4.4 Troubleshooting

Some browsers have a tendency to handle and cache various JavaScript function improperly, and this may cause anomalies and errors in the interface. If you notice improper functionalities, try to clear both the browser history and cache, and refresh the web page.

If this does not clear the problem, please contact Arcteq for further instructions.

6 Software setup

6.1 Functions included in AQ-T3xx

In this chapter are presented the protection and control functions as well as the monitoring functions.

The implemented protection functions are listed in the table below. The function blocks are described in detail in following chapters.

Table. 6.1 - 9. Available protection functions

Function Name	IEC	ANSI	Description
DIF87	$3I_dT>$	87T	Transformer differential protection
DIF87N	REF	87N	Restricted earth fault protection (low impedance)
IOC50	I >>>	50	Three-phase instantaneous overcurrent protection
TOC50_low TOC50_high	I> I>>	51	Three-phase time overcurrent protection
IOC50N	I0 >>>	50N	Residual instantaneous overcurrent protection
TOC51N_low TOC51N_high	I0> I0>>	51N	Residual time overcurrent protection
INR2	I_{2h} >	68	Inrush detection and blocking
VCB60	I_{ub} >	60	Current unbalance protection
TTR49L	T >	49T	Line thermal protection
TOV59_low TOV59_high	U > U >>	59	Definite time overvoltage protection
TUV27_low TUV27_high	U < U <<	27	Definite time undervoltage protection
TOV59N_low TOV59N_high	U0> U0>>	59N	Residual voltage protection
TOF81_high TOF81_low	f > f >>	81O	Overfrequency protection
TUF81_high TUF81_low	f < f <<	81U	Underfrequency protection
FRC81_high FRC81_low	df/dt	81R	Rate of change of frequency protection
VPH24	V/Hz	24	Overexcitation protection (V/Hz)
BRF50MV	CBFP	50BF	Breaker failure protection

Table. 6.1 - 10. Available control and monitoring functions

Name	IEC	ANSI	Description
TRC94	-	94	Trip logic
VTS	-	60	Voltage transformer supervision
SYN25	SYNC	25	Synchro-check function Δf, ΔU, Δφ
AVR	-	-	Integrated voltage regulator (option)
DREC	-	-	Disturbance recorder

6.2 Measurements

6.2.1 Current measurement and scaling

If the factory configuration includes a current transformer hardware module, the current input function block is automatically configured among the software function blocks. Separate current input function blocks are assigned to each current transformer hardware module.

A current transformer hardware module is equipped with four special intermediate current transformers. As usual, the first three current inputs receive the three phase currents (IL1, IL2, IL3), the fourth input is reserved for zero sequence current, for the zero sequence current of the parallel line or for any additional current. Accordingly, the first three inputs have common parameters while the fourth current input needs individual setting.

The role of the current input function block is to

- set the required parameters associated to the current inputs,
- deliver the sampled current values for disturbance recording,
- perform the basic calculations
    - Fourier basic harmonic magnitude and angle,
    - True RMS value;
- provide the pre-calculated current values to the subsequent software function blocks,
- deliver the calculated Fourier basic component values for on-line displaying.

The current input function block receives the sampled current values from the internal operating system. The scaling (even hardware scaling) depends on parameter setting, see parameters Rated Secondary I1-3 and Rated Secondary I4. The options to choose from are 1A or 5A (in special applications, 0.2A or 1A). This parameter influences the internal number format and, naturally, accuracy. A small current is processed with finer resolution if 1A is selected.

If needed, the phase currents can be inverted by setting the parameter Starpoint I1-3. This selection applies to each of the channels IL1, IL2 and IL3. The fourth current channel can be inverted by setting the parameter Direction I4. This inversion may be needed in protection functions such as distance protection, differential protection or for any functions with directional decision.

Figure. 6.2.1 - 33. Example connection.

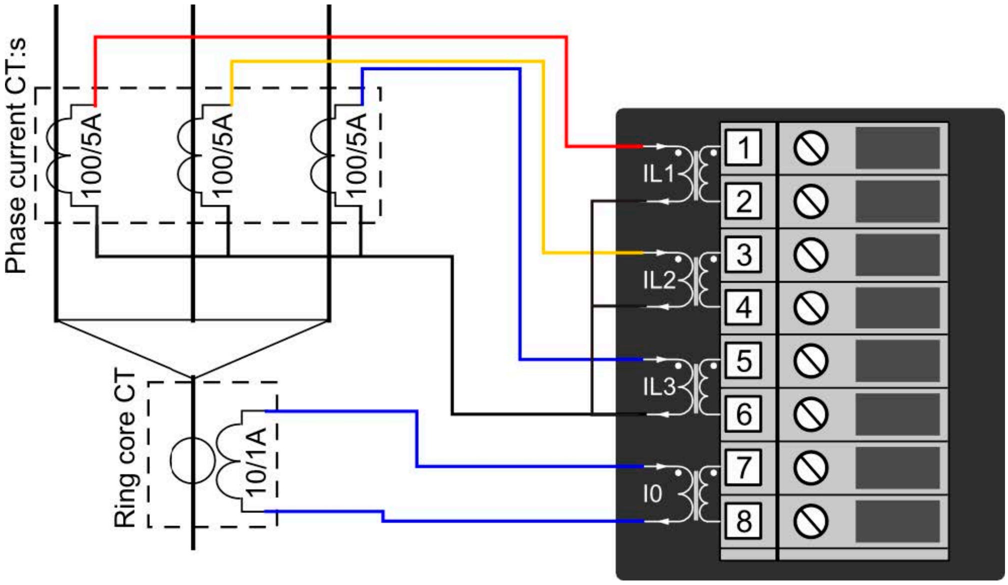


Table. 6.2.1 - 11. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: I0CT primary 10A I0CT secondary 1A
Phase current CT secondary currents starpoint is towards the line.	

Figure. 6.2.1 - 34. Example connection with phase currents connectef into summing "Holmgren" connection into the IO residual input.

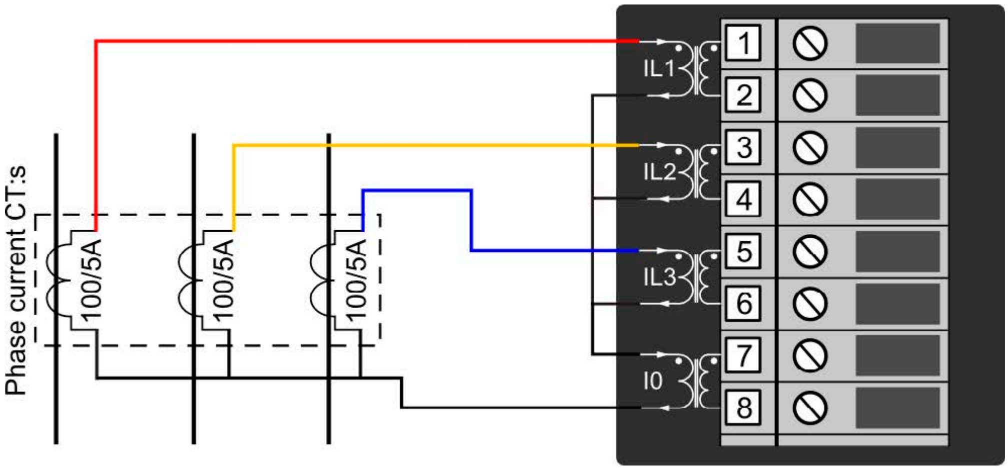


Table. 6.2.1 - 12. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: I0CT primary 100A I0CT secondary 5A
Phase currents are connected to summing "Holmgren" connection into the I0 residual input.	

The sampled values are available for further processing and for disturbance recording.

The performed basic calculation results the Fourier basic harmonic magnitude and angle and the true RMS value. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

The function block also provides parameters for setting the primary rated currents of the main current transformer (Rated Primary I1-3 and Rated Primary I4). This function block does not need that parameter settings. These values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc.

Table. 6.2.1 - 13. Enumerated parameters of the current input function

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table. 6.2.1 - 14. Floating point parameters of the current input function

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_PriI13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_PriI4_FPar_	Rated Primary I4	A	100	4000	1000

Table. 6.2.1 - 15. Online measurements of the current input function

Measured value	Dim.	Explanation
Current Ch - I1	A(secondary)	Fourier basic component of the current in channel IL1
Angle Ch - I1	degree	Vector position of the current in channel IL1
Current Ch - I2	A(secondary)	Fourier basic component of the current in channel IL2
Angle Ch - I2	degree	Vector position of the current in channel IL2
Current Ch - I3	A(secondary)	Fourier basic component of the current in channel IL3

Measured value	Dim.	Explanation
Angle Ch - I3	degree	Vector position of the current in channel IL3
Current Ch - I4	A(secondary)	Fourier basic component of the current in channel I4
Angle Ch - I4	degree	Vector position of the current in channel I4

NOTICE!
The scaling of the Fourier basic component is such that if pure sinusoid 1A RMS of the rated frequency is injected, the displayed value is 1A. The displayed value does not depend on the parameter setting values “Rated Secondary”.

NOTICE!
The reference of the vector position depends on the device configuration. If a voltage input module is included, then the reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. If no voltage input module is configured, then the reference vector (vector with angle 0 degree) is the vector calculated for the first current input channel of the first applied current input module. (The first input module is the one, configured closer to the CPU module.)

6.2.2 Voltage measurement and scaling

If the factory configuration includes a voltage transformer hardware module, the voltage input function block is automatically configured among the software function blocks. Separate voltage input function blocks are assigned to each voltage transformer hardware module.

A voltage transformer hardware module is equipped with four special intermediate voltage transformers. As usual, the first three voltage inputs receive the three phase voltages (UL1, UL2, UL3), the fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchro switching.

The role of the voltage input function block is to

- set the required parameters associated to the voltage inputs,
- deliver the sampled voltage values for disturbance recording,
- perform the basic calculations
    - Fourier basic harmonic magnitude and angle,
    - True RMS value;
- provide the pre-calculated voltage values to the subsequent software modules,
- deliver the calculated basic Fourier component values for on-line displaying.

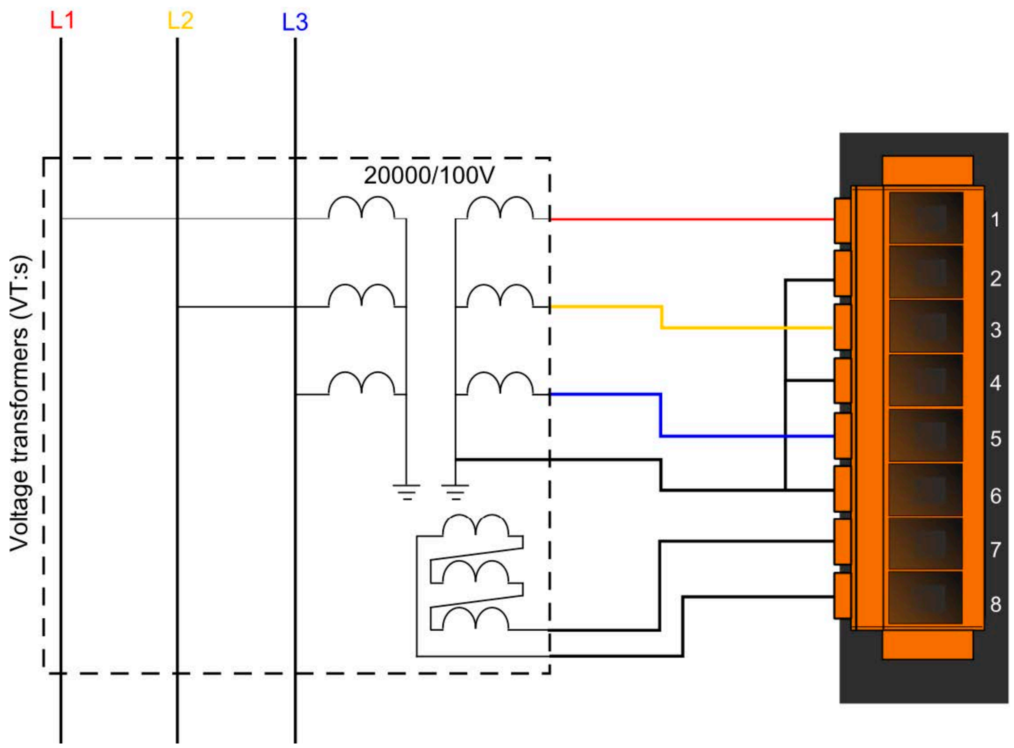
The voltage input function block receives the sampled voltage values from the internal operating system. The scaling (even hardware scaling) depends on a common parameter “Range” for type selection. The options to choose from are 100V or 200V, no hardware modification is needed. A small voltage is processed with finer resolution if 100V is selected. This parameter influences the internal number format and, naturally, accuracy.

There is a correction factor available if the rated secondary voltage of the main voltage transformer (e.g. 110V) does not match the rated input of the device. The related parameter is “VT correction“. As an example: if the rated secondary voltage of the main voltage transformer is 110V, then select Type 100 for the parameter “Range” and the required value to set here is 110%.

The connection of the first three VT secondary windings must be set to reflect actual physical connection of the main VTs. The associated parameter is “Connection U1-3“. The selection can be: Ph-N, Ph-Ph or Ph-N-Isolated.

The Ph-N option is applied in solidly grounded networks, where the measured phase voltage is never above 1.5-Un. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

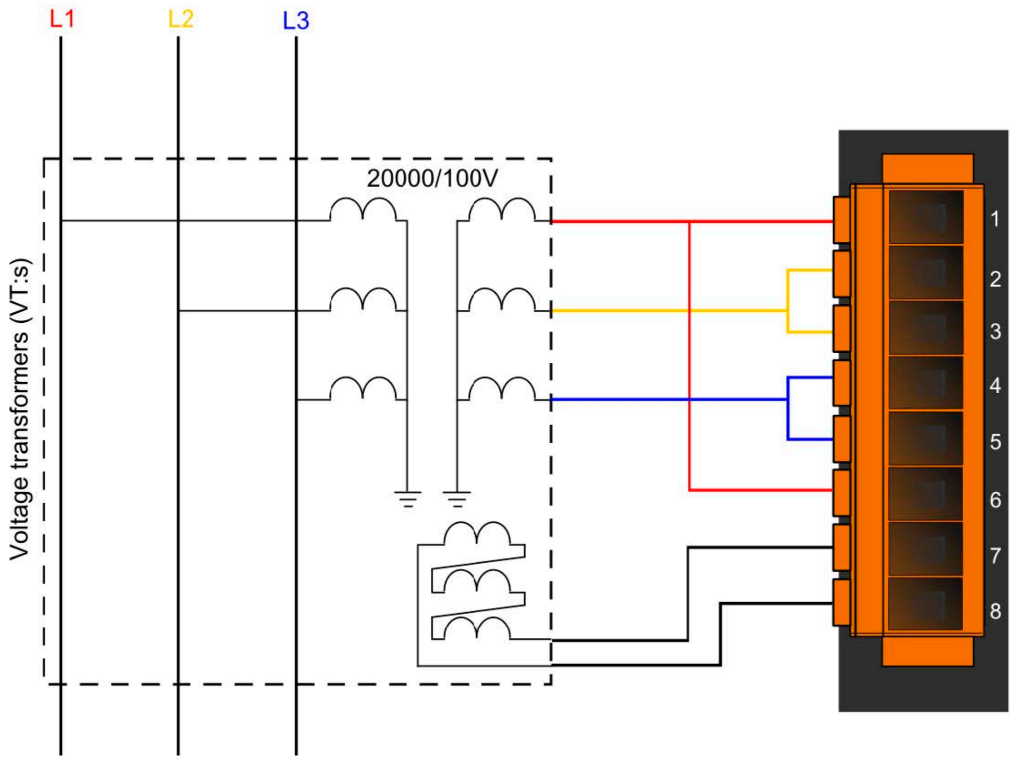
Figure. 6.2.2 - 35. Phase to neutral connection. Connection U1-3.



Ph-N Voltage: Rated Primary U1-3: 11.55kV (=20kV/√3) Range: Type 100	Residual voltage: Rated Primary U4: 11.54A

If phase-to-phase voltage is connected to the VT input of the device, then the Ph-Ph option is to be selected. Here, the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage. This option must not be selected if the distance protection function is supplied from the VT input.

Figure. 6.2.2 - 36. Phase-to-phase connection.



Ph-N Voltage: Rated Primary U1-3: 20kV Range: Type 100	Residual voltage: Rated Primary U4: 11.54A (=20kV/√3)

The fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchron switching. Accordingly, the connected voltage must be identified with parameter setting “Connection U4“. Here, phase-to-neutral or phase-to-phase voltage can be selected: Ph-N, Ph-Ph.

If needed, the phase voltages can be inverted by setting the parameter “Direction U1-3“. This selection applies to each of the channels UL1, UL2 and UL3. The fourth voltage channel can be inverted by setting the parameter “Direction U4“. This inversion may be needed in protection functions such as distance protection or for any functions with directional decision, or for checking the voltage vector positions.

These modified sampled values are available for further processing and for disturbance recording.

The function block also provides parameters for setting the primary rated voltages of the main voltage transformers. This function block does not need that parameter setting but these values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc.

Table. 6.2.2 - 16. Enumerated parameters of the voltage input function

Parameter name	Title	Selection range	Default
Rated secondary voltage of the input channels. 100 V or 200V type is selected by parameter setting, no hardware modification is needed.			
VT4_Type_EPar_	Range	Type 100,Type 200	Type 100
Connection of the first three voltage inputs (main VT secondary)			

Parameter name	Title	Selection range	Default
VT4_Ch13Nom_EPar_	Connection U1-3	Ph-N, Ph-Ph, Ph-N-Isolated	Ph-N
Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage			
VT4_Ch4Nom_EPar_	Connection U4	Ph-N,Ph-Ph	Ph-Ph
Definition of the positive direction of the first three input channels, given as normal or inverted			
VT4_Ch12Dir_EPar_	Direction U1-3	Normal,Inverted	Normal
Definition of the positive direction of the fourth voltage, given as normal or inverted			
VT4_Ch4Dir_EPar_	Direction U4	Normal,Inverted	Normal

Table. 6.2.2 - 17. Integer parameters of the voltage input function

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage correction						
VT4_CorrFact_IPar_	VT correction	%	100	115	1	100

Table. 6.2.2 - 18. Float point parameters of the voltage input function

Parameter name	Title	Dim.	Min	Max	Default
Rated primary voltage of channel1					
VT4_PriU1_FPar_	Rated Primary U1	kV	1	1000	100
Rated primary voltage of channel2					
VT4_PriU2_FPar_	Rated Primary U2	kV	1	1000	100
Rated primary voltage of channel3					
VT4_PriU3_FPar_	Rated Primary U3	kV	1	1000	100
Rated primary voltage of channel4					
VT4_PriU4_FPar_	Rated Primary U4	kV	1	1000	100

NOTICE!
The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

Table. 6.2.2 - 19. On-line measured analogue values of the voltage input function

Measured value	Dim.	Explanation
Voltage Ch - U1	V(secondary)	Fourier basic component of the voltage in channel UL1
Angle Ch - U1	degree	Vector position of the voltage in channel UL1
Voltage Ch - U2	V(secondary)	Fourier basic component of the voltage in channel UL2

Measured value	Dim.	Explanation
Angle Ch - U2	degree	Vector position of the voltage in channel UL2
Voltage Ch - U3	V(secondary)	Fourier basic component of the voltage in channel UL3
Angle Ch - U3	degree	Vector position of the voltage in channel UL3
Voltage Ch - U4	V(secondary)	Fourier basic component of the voltage in channel U4
Angle Ch - U4	degree	Vector position of the voltage in channel U4

NOTICE!
The scaling of the Fourier basic component is such if pure sinusoid 57V RMS of the rated frequency is injected, the displayed value is 57V. The displayed value does not depend on the parameter setting values “Rated Secondary”.

NOTICE!
The reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. The first voltage input module is the one, configured closer to the CPU module.

6.2.3 Line measurement

The input values of the AQ300 devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the measured transformer parameters, the “Line measurement” function block calculates - depending on the hardware and software configuration - the primary RMS values of the voltages and currents and some additional values such as active and reactive power, symmetrical components of voltages and currents. These values are available as primary quantities and they can be displayed on the on-line screen of the device or on the remote user interface of the computers connected to the communication network and they are available for the SCADA system using the configured communication system.

Reporting the measured values and the changes

It is usual for the SCADA systems that they sample the measured and calculated values in regular time periods and additionally they receive the changed values as reports at the moment when any significant change is detected in the primary system. The “Line measurement” function block is able to perform such reporting for the SCADA system.

Operation of the line measurement function block

The inputs of the line measurement function are

- the Fourier components and true RMS values of the measured voltages and currents
- frequency measurement
- parameters.

The outputs of the line measurement function are

- displayed measured values
- reports to the SCADA system.

NOTICE!
The scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.

Measured values

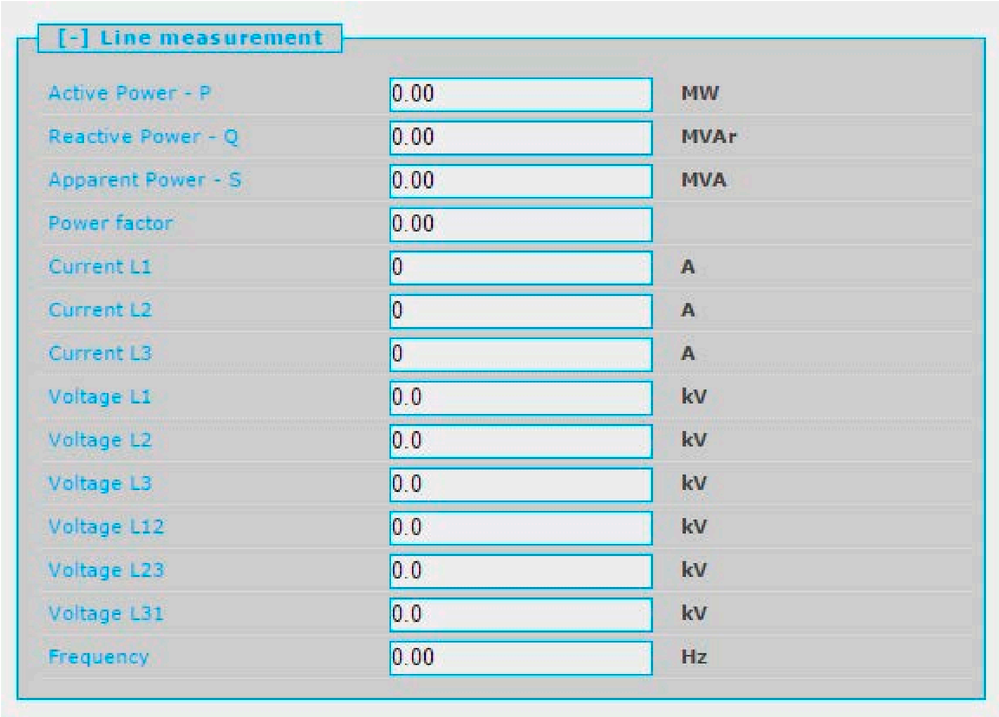
The measured values of the line measurement function depend on the hardware configuration. As an example, table shows the list of the measured values available in a configuration for solidly grounded networks.

Table. 6.2.3 - 20. Example: Measured values in a configuration for solidly grounded networks

Measured value	Explanation
MXU_P_OLM_	Active Power — P (Fourier base harmonic value)
MXU_Q_OLM_	Reactive Power — Q (Fourier base harmonic value)
MXU_S_OLM	Apparent Power — S (Fourier base harmonic value)
MXU_I1_OLM_	Current L1
MXU_I2_OLM_	Current L2
MXU_I3_OLM_	Current L3
MXU_U1_OLM_	Voltage L1
MXU_U2_OLM_	Voltage L2
MXU_U3_OLM_	Voltage L3
MXU_U12_OLM_	Voltage L12
MXU_U23_OLM_	Voltage L23
MXU_U31_OLM_	Voltage L31
MXU_f_OLM_	Frequency

Another example is in figure, where the measured values available are shown as on-line information in a configuration for compensated networks.

Figure. 6.2.3 - 37. Measured values in a configuration for compensated networks.



The available quantities are described in the configuration description documents.

Reporting the measured values and the changes

For reporting, additional information is needed, which is defined in parameter setting. As an example, in a configuration for solidly grounded networks the following parameters are available:

Table. 6.2.3 - 21. The enumerated parameters of the line measurement function.

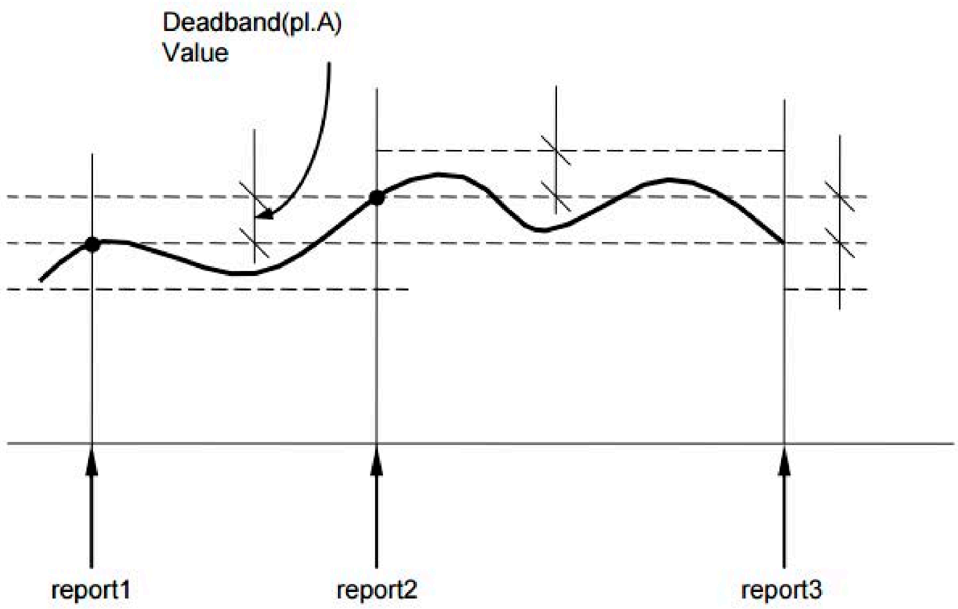
Parameter name	Title	Selection range	Default
Selection of the reporting mode for active power measurement			
MXU_PRepMode_EPar_	Operation ActivePower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for reactive power measurement			
MXU_QRepMode_EPar_	Operation ReactivePower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for apparent power measurement			
MXU_SRepMode_EPar_	Operation ApparPower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for current measurement			
MXU_IRepMode_EPar_	Operation Current	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for voltage measurement			
MXU_URepMode_EPar_	Operation Voltage	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for frequency measurement			
MXU_fRepMode_EPar_	Operation Frequency	Off, Amplitude, Integrated	Amplitude

The selection of the reporting mode items is explained in next chapters.

"Amplitude" mode of reporting

If the "Amplitude" mode is selected for reporting, a report is generated if the measured value leaves the deadband around the previously reported value. As an example, the figure below shows that the current becomes higher than the value reported in "report1" PLUS the Deadband value, this results "report2", etc.

Figure. 6.2.3 - 38. Reporting when Amplitude mode is selected.



For this mode of operation, the Deadband parameters are explained in table below.

The "Range" parameters in the table are needed to evaluate a measurement as "out-of-range".

Table. 6.2.3 - 22. The enumerated parameters of the line measurement function.

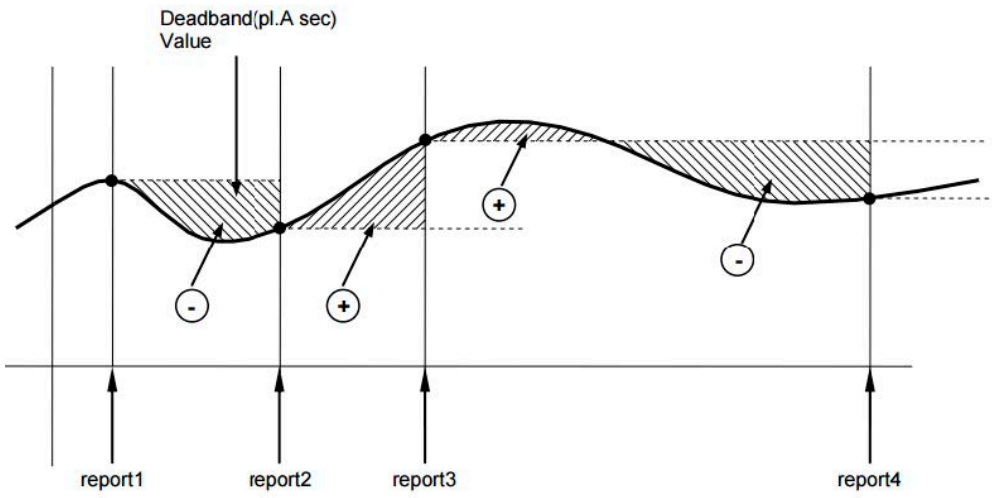
Parameter name	Title	Dim.	Min	Max	Step	Default
Deadband value for the active power						
MXU_PDeadB_FPar_	Deadband value - P	MW	0.1	100000	0.01	10
Range value for the active power						
MXU_PRange_FPar_	Range value - P	MW	1	100000	0.01	500
Deadband value for the reactive power						
MXU_QDeadB_FPar_	Deadband value - Q	MVar	0.1	100000	0.01	10
Range value for the reactive power						
MXU_QRange_FPar_	Range value - Q	MVar	1	100000	0.01	500
Deadband value for the apparent power						
MXU_SDeadB_FPar_	Deadband value - S	MVA	0.1	100000	0.01	10

Parameter name	Title	Dim.	Min	Max	Step	Default
Range value for the apparent power						
MXU_SRange_FPar_	Range value - S	MVA	0.1	100000	0.01	500
Deadband value for the current						
MXU_IDeadB_FPar_	Deadband value - I	A	1	2000	1	10
Range value for the current						
MXU_IRange_FPar_	Range value - I	A	1	5000	1	500
Deadband value for the phase-to-neutral voltage						
MXU_UPhDeadB_FPar_	Deadband value - U ph-N	kV	0.1	100	0.01	1
Range value for the phase-to-neutral voltage						
MXU_UPhRange_FPar_	Range value - U ph-N	kV	1	1000	0.1	231
Deadband value for the phase-to-phase voltage						
MXU_UPPDeadB_FPar_	Deadband value - U ph-ph	kV	0.1	100	0.01	1
Range value for the phase-to-phase voltage						
MXU_UPPRange_FPar_	Range value - U ph-ph	kV	1	1000	0.1	400
Deadband value for the frequency						
MXU_fDeadB_FPar_	Deadband value - f	Hz	0.01	1	0.01	0.02
Range value for the frequency						
MXU_fRange_FPar_	Range value - f	Hz	0.05	10	0.01	5

"Integral" mode of reporting

If the “Integrated” mode is selected for reporting, a report is generated if the time integral of the measured value since the last report gets becomes larger, in the positive or negative direction, then the (deadband*1sec) area. As an example, the figure below shows that the integral of the current in time becomes higher than the Deadband value multiplied by 1sec, this results “report2”, etc.

Figure. 6.2.3 - 39. Reporting when Integrated mode is selected.



Periodic reporting

Periodic reporting is generated independently of the changes of the measured values when the defined time period elapses.

Table. 6.2.3 - 23. The floating-point parameters of the line measurement function

Parameter name	Title	Dim.	Min	Max	Step	Default
Deadband value for the active power						
MXU_PDeadB_FPar_	Deadband value - P	MW	0.1	100000	0.01	10
Range value for the active power						
MXU_PRange_FPar_	Range value - P	MW	1	100000	0.01	500
Deadband value for the reactive power						
MXU_QDeadB_FPar_	Deadband value - Q	MVar	0.1	100000	0.01	10
Range value for the reactive power						
MXU_QRange_FPar_	Range value - Q	MVar	1	100000	0.01	500
Deadband value for the apparent power						
MXU_SDeadB_FPar_	Deadband value - S	MVA	0.1	100000	0.01	10
Range value for the apparent power						
MXU_SRange_FPar_	Range value - S	MVA	0.1	100000	0.01	500
Deadband value for the current						
MXU_IDeadB_FPar_	Deadband value - I	A	1	2000	1	10
Range value for the current						
MXU_IRange_FPar_	Range value - I	A	1	5000	1	500

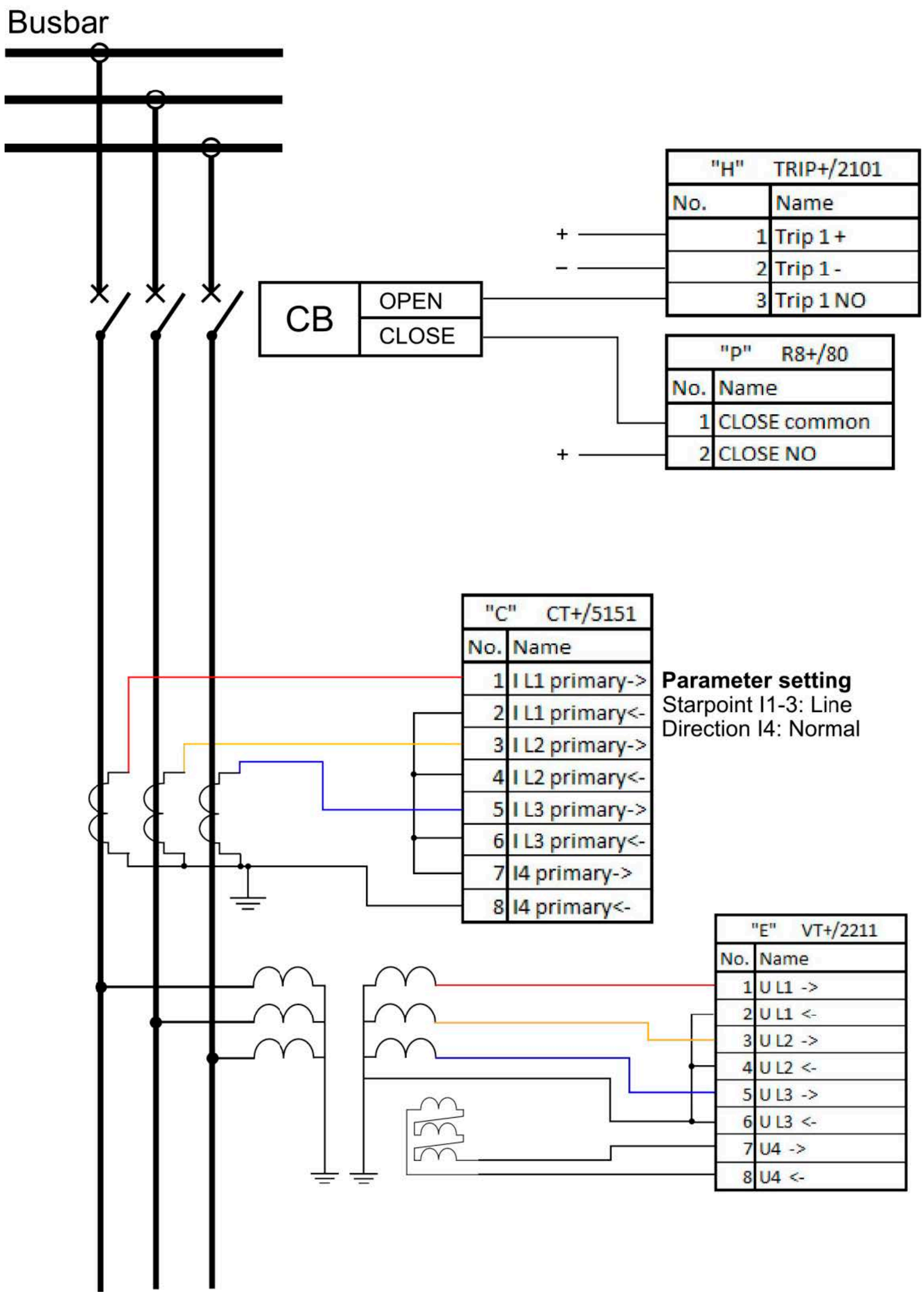
Parameter name	Title	Dim.	Min	Max	Step	Default
Deadband value for the phase-to-neutral voltage						
MXU_UPhDeadB_FPar_	Deadband value - U ph-N	kV	0.1	100	0.01	1
Range value for the phase-to-neutral voltage						
MXU_UPhRange_FPar_	Range value - U ph-N	kV	1	1000	0.1	231
Deadband value for the phase-to-phase voltage						
MXU_UPPDeadB_FPar_	Deadband value - U ph-ph	kV	0.1	100	0.01	1
Range value for the phase-to-phase voltage						
MXU_UPPRange_FPar_	Range value - U ph-ph	kV	1	1000	0.1	400
Deadband value for the frequency						
MXU_fDeadB_FPar_	Deadband value - f	Hz	0.01	1	0.01	0.02
Range value for the frequency						
MXU_fRange_FPar_	Range value - f	Hz	0.05	10	0.01	5

If the reporting time period is set to 0, then no periodic reporting is performed for this quantity. All reports can be disabled for a quantity if the reporting mode is set to “Off”.

6.2.4 Measurement connection examples

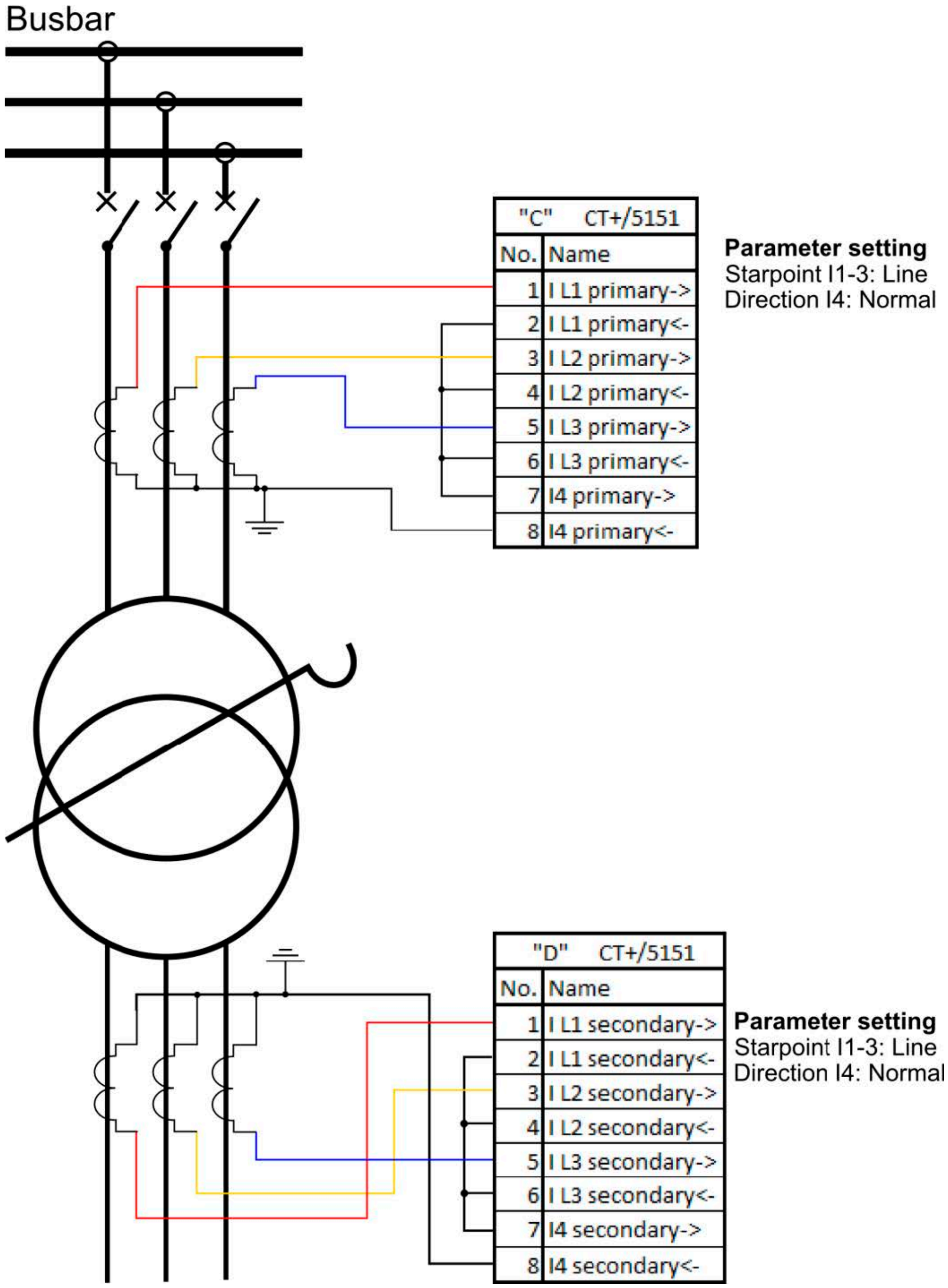
Connection example with a current breaker

Figure. 6.2.4 - 40. Connection example with a current breaker (open and closed connections, CT and VT connection).



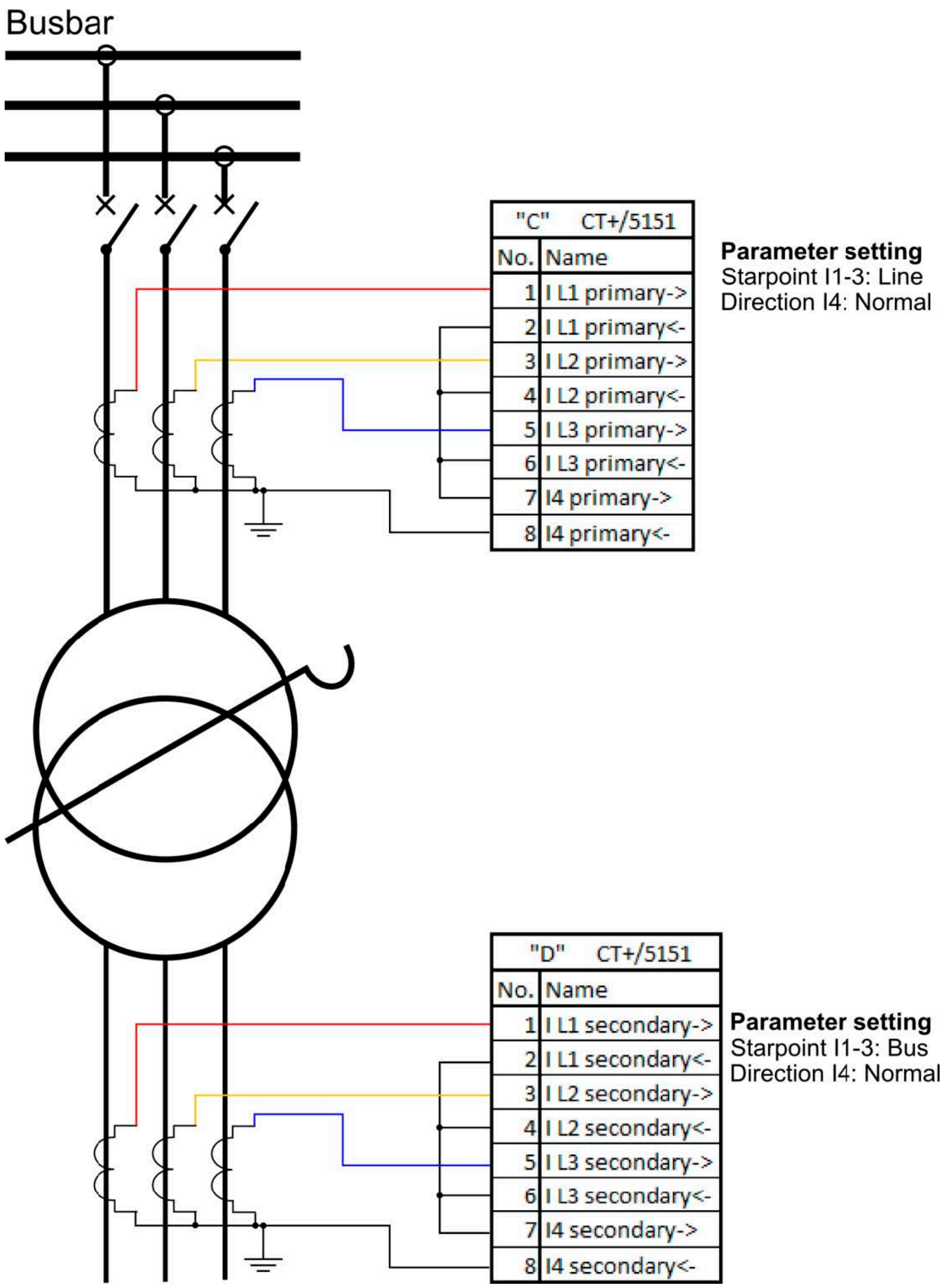
Connection example with two CTs (facing)

Figure. 6.2.4 - 41. Connection example with two CTs facing each other.



Connection example with two CTs (inverted secondary)

Figure. 6.2.4 - 42. Connection example with two CTs (the direction of the secondary side's starpoint has been inverted).

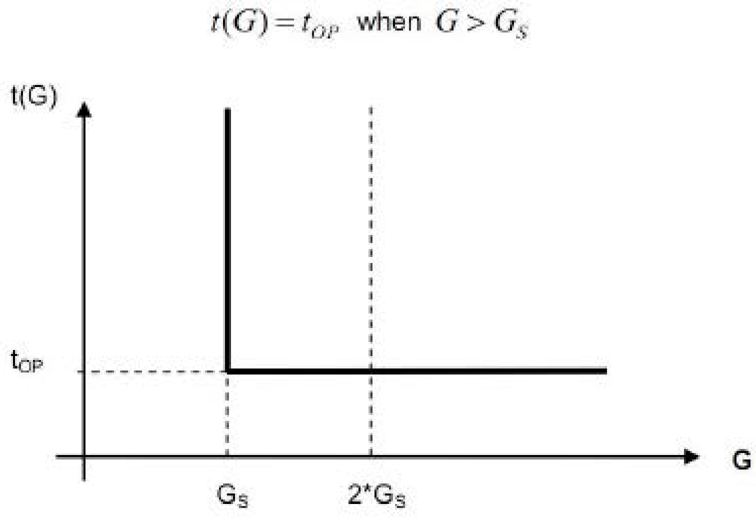


6.3 Protection functions

6.3.1 Three-phase instantaneous overcurrent protection (I>; 50/51)

The instantaneous overcurrent protection function operates according to instantaneous characteristics, using the three sampled phase currents. The setting value is a parameter, and it can be doubled with dedicated input binary signal. The basic calculation can be based on peak value selection or on Fourier basic harmonic calculation, according to the parameter setting.

Figure. 6.3.1 - 43. Operating characteristics of the instantaneous overcurrent protection function.



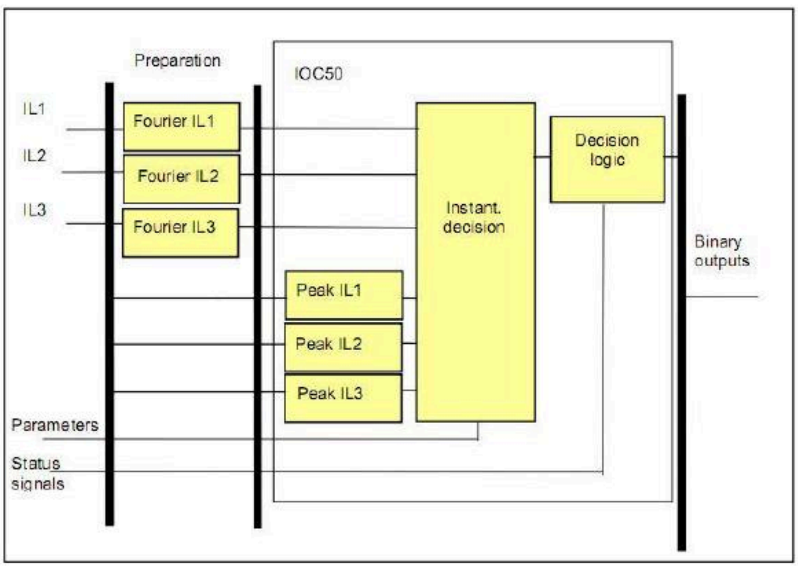
The variables in the image above are:

- t_{OP} (seconds) = theoretical operating time if $G>G_S$ (without additional time delay)
- G = measured peak value or Fourier base harmonic of the phase currents
- G_S = pick-up setting value

The structure of the algorithm consists of following modules. Fourier calculation module calculates the RMS values of the Fourier components of the residual current. Peak selection module is an alternative for the Fourier calculation module and the peak selection module selects the peak values of the phase currents individually. Instantaneous decision module compares the peak- or Fourier basic harmonic components of the phase currents into the setting value. Decision logic module generates the trip signal of the function.

In the figure below. is presented the structure of the instantaneous overcurrent algorithm.

Figure. 6.3.1 - 44. The structure of the function's algorithm.



The algorithm generates a trip command without additional time delay based on the Fourier components of the phase currents or peak values of the phase currents in case if the user set pick-up value is exceeded. The operation of the function is phase wise and it allows each phase to be tripped separately. Standard operation is three poles.

The function includes a blocking signal input which can be configured by user from either IED internal binary signals or IED binary inputs through the programmable logic.

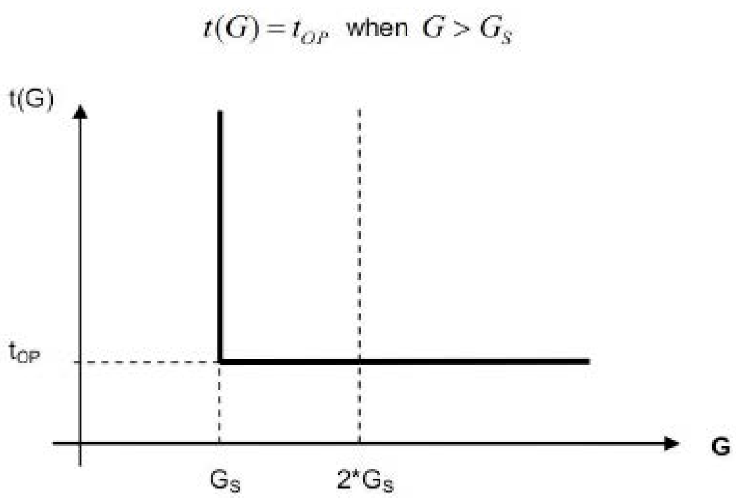
Table. 6.3.1 - 24. Setting parameters of the instantaneous overcurrent protection function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off Peak value Fundamental value	-	Peak value	Operating mode selection of the function. Can be disabled, operating based into measured current peak values or operating based into calculated current fundamental frequency RMS values.
Start current	20…3000 %In	1 %In	200 %In	Pick-up setting of the function.

6.3.2 Residual instantaneous overcurrent protection (I0>; 50N/51N)

The residual instantaneous overcurrent protection function operates according to instantaneous characteristics, using the residual current (IN=3Io). The setting value is a parameter, and it can be doubled with dedicated input binary signal. The basic calculation can be based on peak value selection or on Fourier basic harmonic calculation, according to the parameter setting.

Figure. 6.3.2 - 45. Operating characteristics of the residual instantaneous overcurrent protection function.



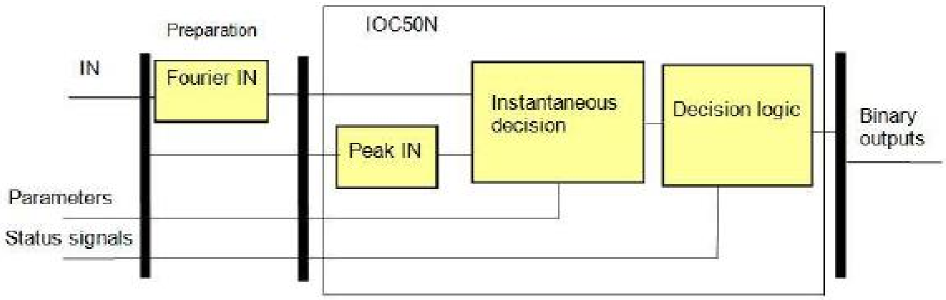
The variables in the image above are:

- t_{OP} (seconds) = theoretical operating time if $G>G_S$ (without additional time delay)
- G = measured peak value or Fourier base harmonic of the residual current
- G_S = pick-up setting value

The structure of the algorithm consists of following modules. Fourier calculation module calculates the RMS values of the Fourier components of the residual current. Peak selection module is an alternative for the Fourier calculation module and the peak selection module selects the peak values of the residual currents individually. Instantaneous decision module compares the peak- or Fourier basic harmonic components of the phase currents into the setting value. Decision logic module generates the trip signal of the function.

Below is presented the structure of the instantaneous residual overcurrent algorithm.

Figure. 6.3.2 - 46. The structure of the residual instantaneous overcurrent algorithm.



The algorithm generates a trip command without additional time delay based on the Fourier components of the phase currents or peak values of the phase currents in case if the user set pick-up value is exceeded. The operation of the function is phase wise and it allows each phase to be tripped separately. Standard operation is three poles.

The function includes a blocking signal input which can be configured by user from either IED internal binary signals or IED binary inputs through the programmable logic.

Table. 6.3.2 - 25. Setting parameters of the residual instantaneous overcurrent protection function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off Peak value Fundamental value	-	Peak value	Operating mode selection of the function. Can be disabled, operating based into measured current peak values or operating based into calculated current fundamental frequency RMS values.
Start current	10…400 %In	1 %In	200 %In	Pick-up setting of the function.

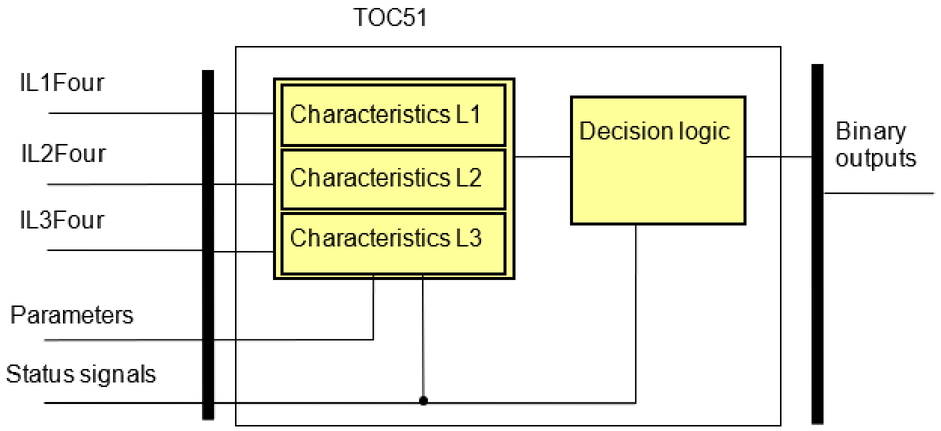
6.3.3 Three-phase time overcurrent protection (I>; 50/51)

Three phase time overcurrent function includes the definite time and IDMT characteristics according to the IEC and IEEE standards. The function measures the fundamental Fourier components of the measured three phase currents.

The structure of the algorithm consists of following modules. Fourier calculation module calculates the RMS values of the Fourier components of the 3-phase currents. Characteristics module compares the Fourier basic harmonic components of the phase currents into the setting value. Decision logic module generates the trip signal of the function.

In the figure below is presented the structure of the time overcurrent algorithm.

Figure. 6.3.3 - 47. The structure of the time overcurrent algorithm.

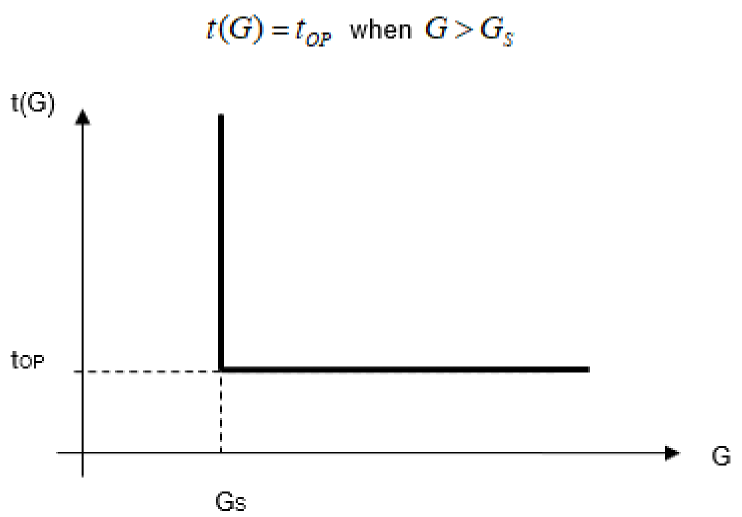


The algorithm generates a start signal based on the Fourier components of the phase currents or peak values of the phase currents in case if the user set pick-up value is exceeded. Trip signal is generated based into the selected definite time- or IDMT additional time delay is passed from the start conditions. The operation of the function is phase wise and it allows each phase to be tripped separately. Standard operation is three poles.

The function includes a blocking signal input which can be configured by user from either IED internal binary signals or IED binary inputs through the programmable logic.

Operating characteristics of the definite time is presented in the figure below.

Figure. 6.3.3 - 48. Operating characteristics of the instantaneous overcurrent protection function.



The variables in the image above are:

- t_{OP} (seconds) = theoretical operating time if $G>G_S$ (without additional time delay)
- G = measured peak value or Fourier base harmonic of the phase currents
- G_S = pick-up setting value

IDMT operating characteristics depend on the selected curve family and curve type. All of the available IDMT characteristics follow

$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - 1} + c\right]$$

The variables of the equation above are:

- t(G) (seconds) = theoretical operate time with constant value of G, when $G > G_S$
- k, c = contants characterizing the selected curve
- α = constant characterizing the selected curve
- G = measured value of the Fourier base harmonic of the phase currents
- G_S = pick-up setting value
- TMS = time dial setting / preset time multiplier

The parameters and operating curve types follow corresponding standards presented in the table below.

Table. 6.3.3 - 26. Parameters and operating curve types for the IDMT characteristics.

Curve family	Characteristics	k_r	c	α
IEC	NI (normally inverse)	0.14	0	0.02
IEC	VI (very inverse)	13.5	0	1
IEC	EI (extremely inverse)	80	0	2
IEC	LTI (long time inverse)	120	0	1
IEEE/ANSI	NI (normally inverse)	0.0086	0.0185	0.02
IEEE/ANSI	MI (moderately inverse)	0.0515	0.1140	0.02
IEEE/ANSI	VI (very inverse)	19.61	0.491	2
IEEE/ANSI	EI (extremely inverse)	28.2	0.1217	2
IEEE/ANSI	LTI (long time inverse)	0.086	0.185	0.02
IEEE/ANSI	LTVI (long time, very inverse)	28.55	0.712	2
IEEE/ANSI	LTEI (long time, extremely inverse)	64.07	0.250	2

In following figures the characteristics of IDMT curves are presented with minimum and maximum pick-up settings in respect of the IED measuring range.

Figure. 6.3.3 - 49. IEC - NI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

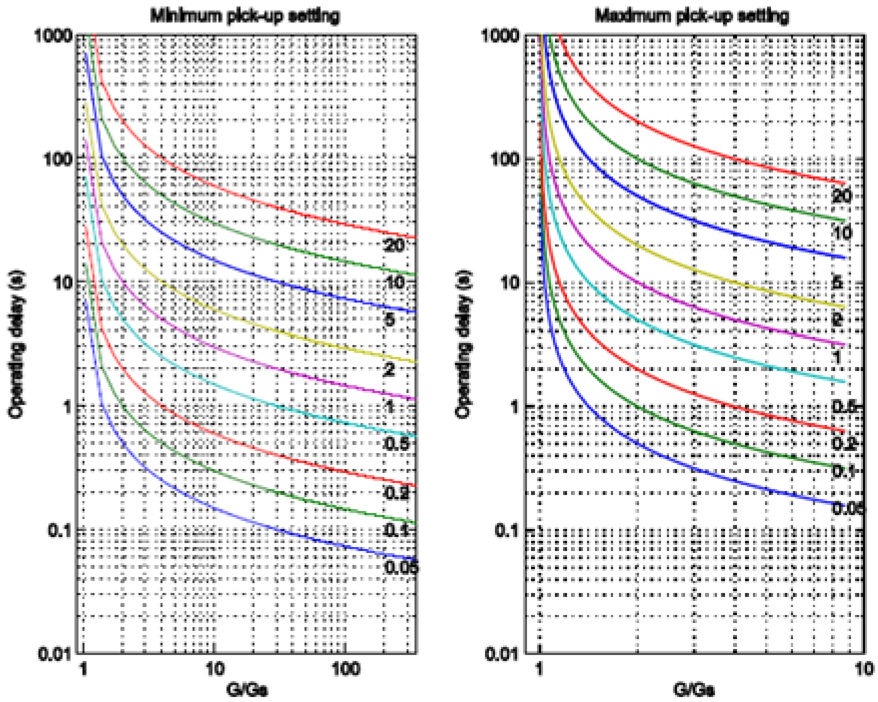


Figure. 6.3.3 - 50. IEC - VI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

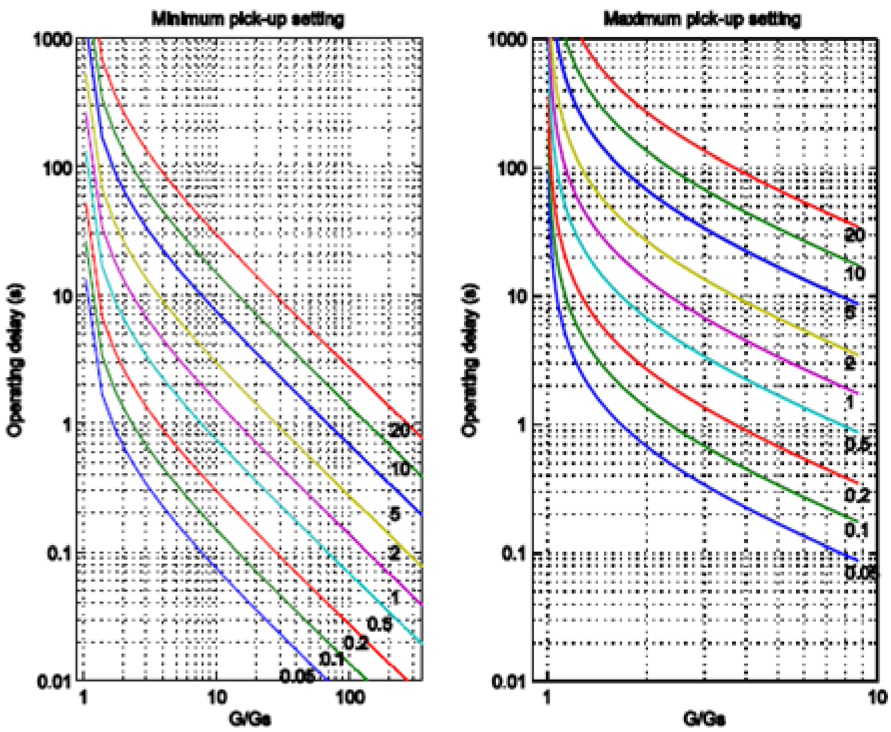


Figure. 6.3.3 - 51. IEC - EI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

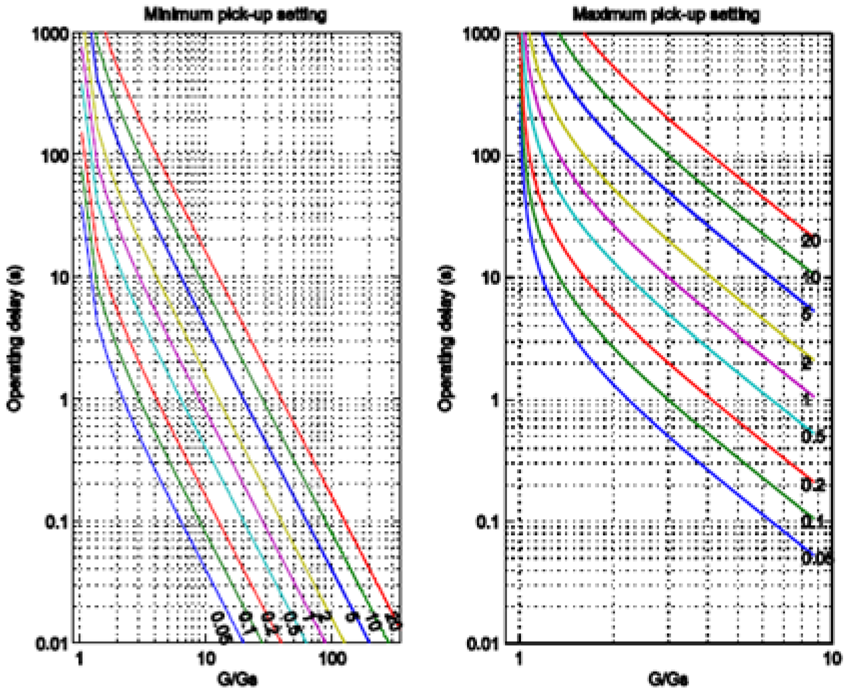


Figure. 6.3.3 - 52. IEC - LTI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

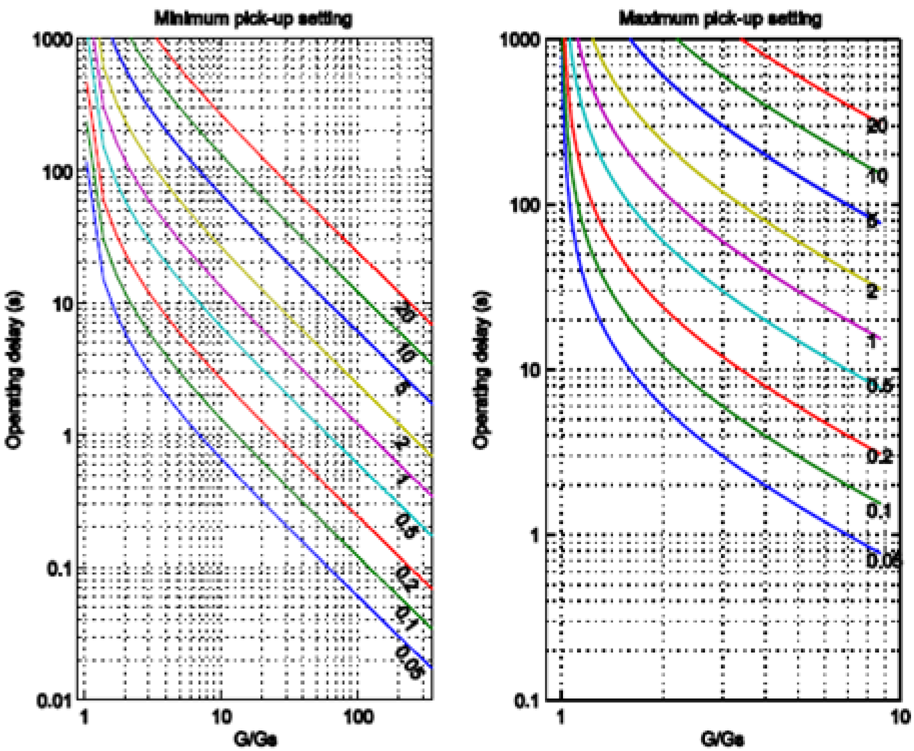


Figure. 6.3.3 - 53. IEEE/ANSI - NI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

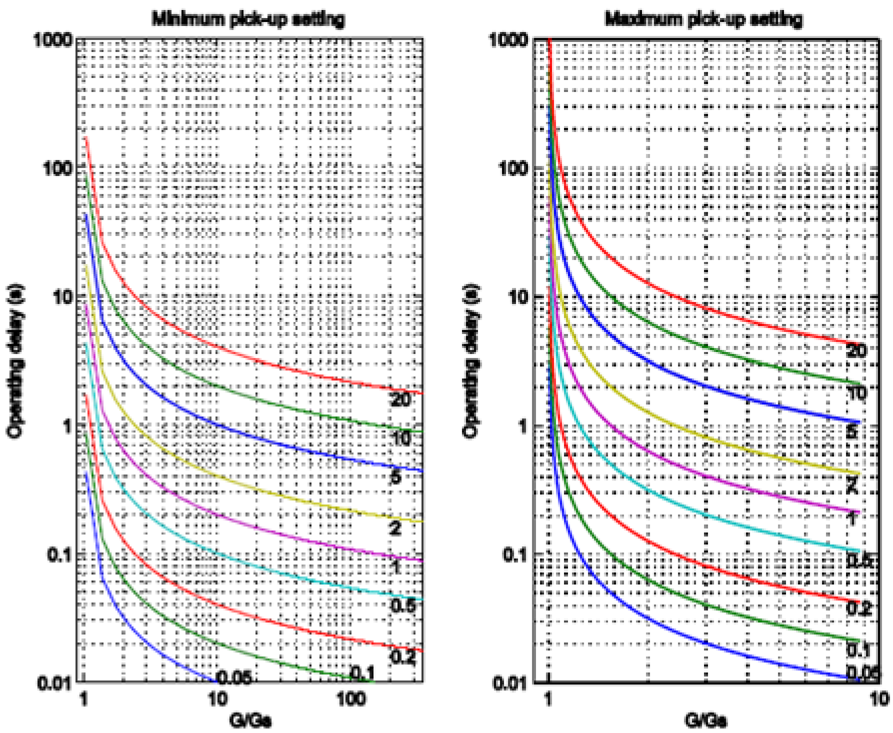


Figure. 6.3.3 - 54. IEEE/ANSI - MI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

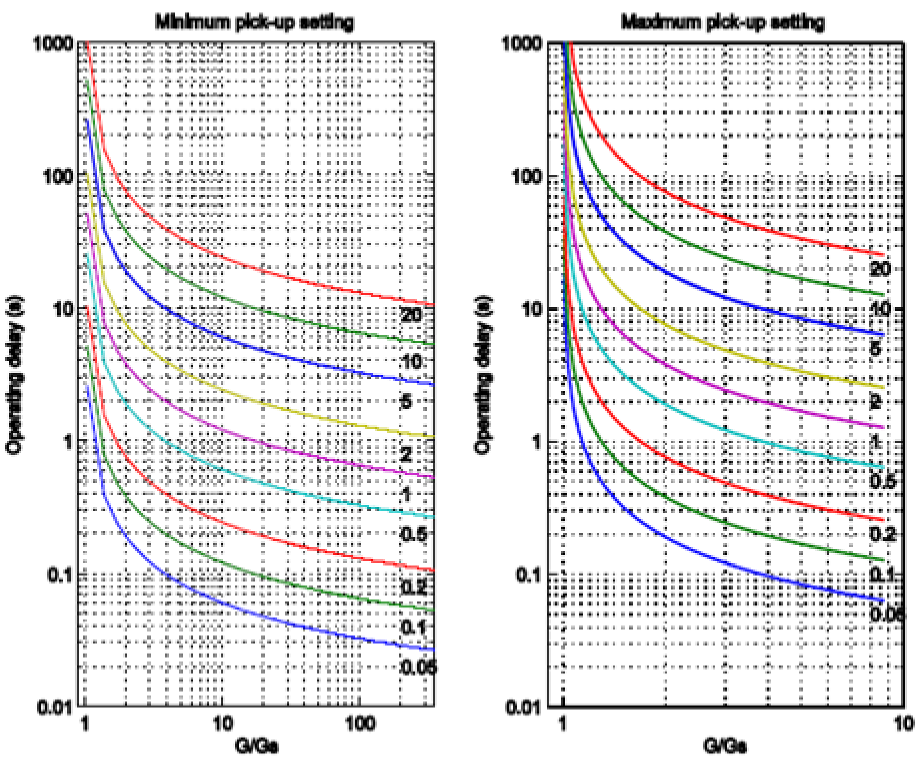


Figure. 6.3.3 - 55. IEEE/ANSI - VI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

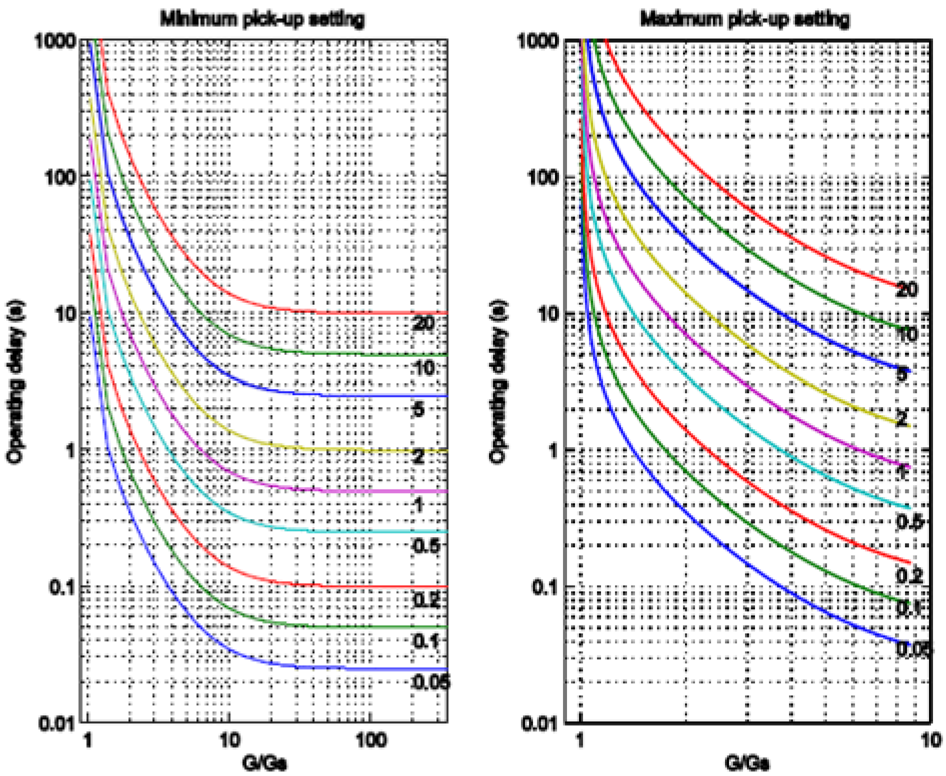


Figure. 6.3.3 - 56. IEEE/ANSI - EI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

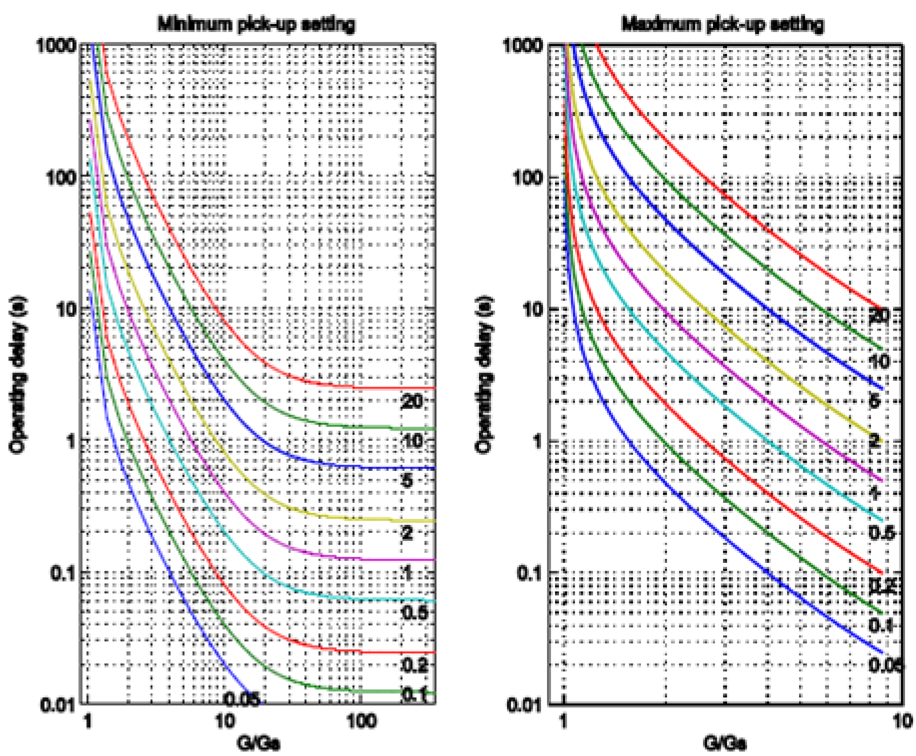


Figure. 6.3.3 - 57. IEEE/ANSI - LTI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

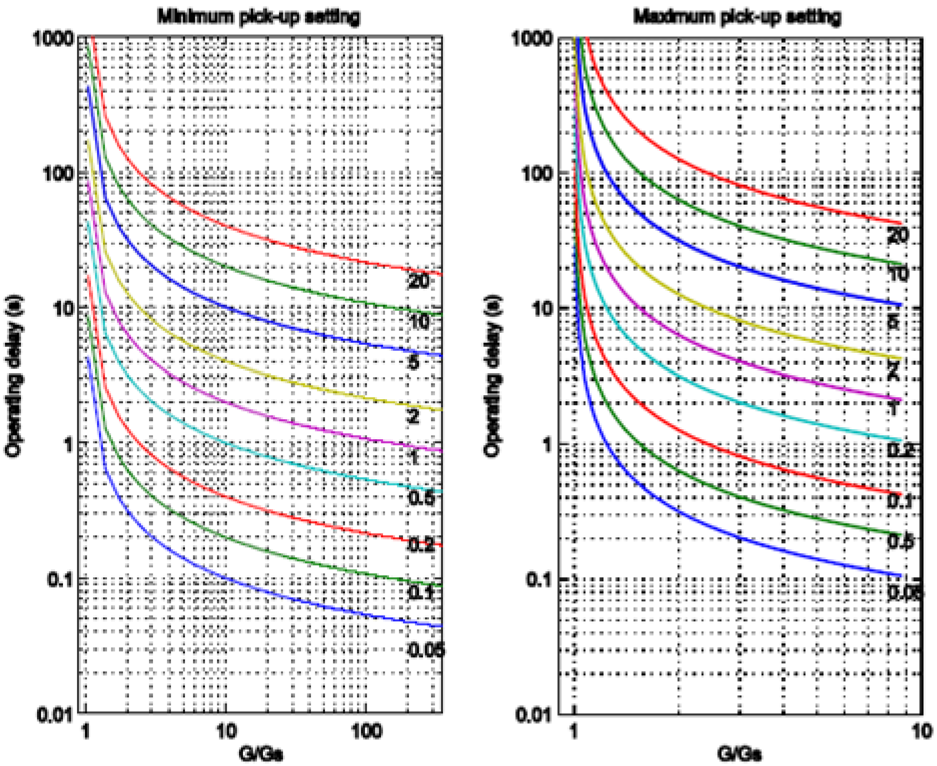


Figure. 6.3.3 - 58. IEEE/ANSI - LTVI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.

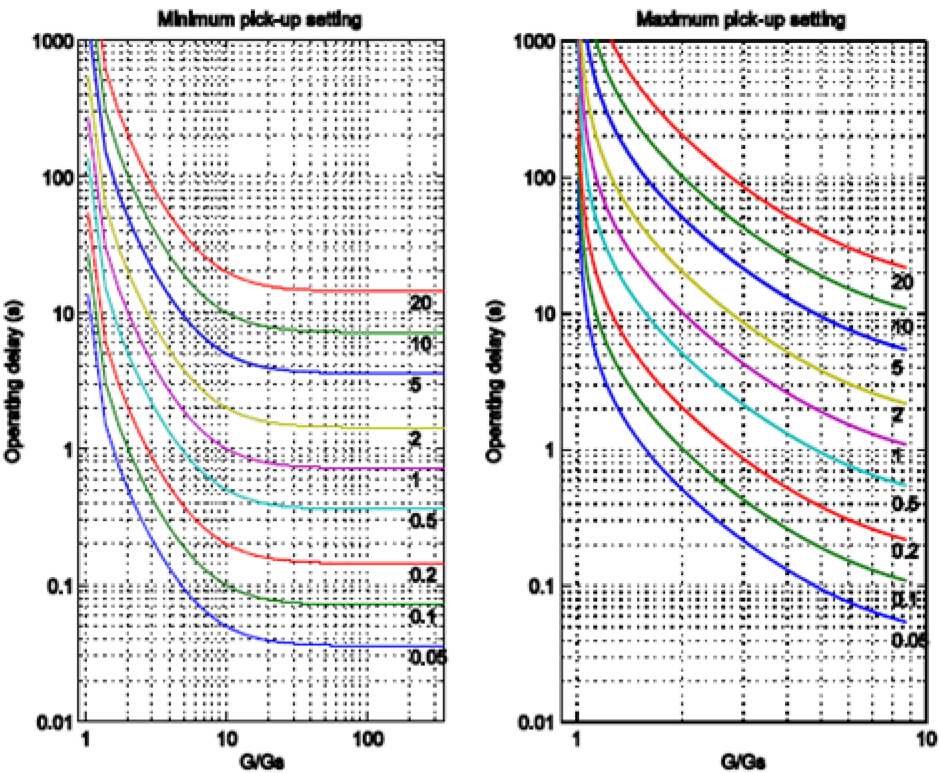
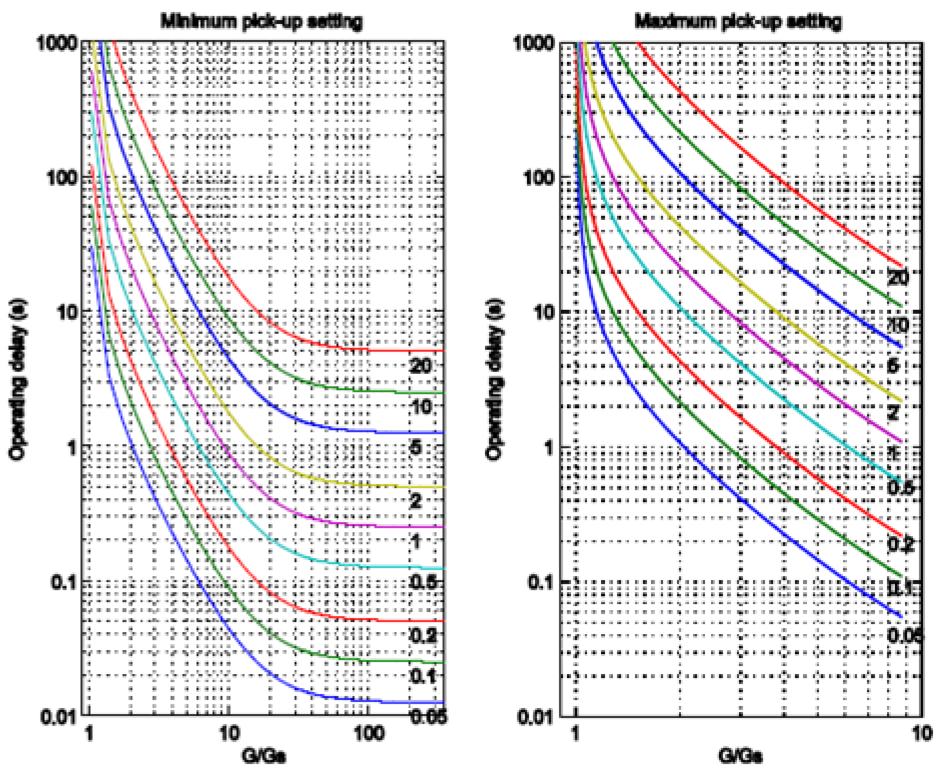


Figure. 6.3.3 - 59. IEEE/ANSI - LTEI operating curves with minimum and maximum pick-up settings and TMS settings from 0.05 to 20.



Resetting characteristics for the function depends on the selected operating time characteristics. For the IEC type IDMT characteristics the reset time is user settable and for the ANSI/IEEE type characteristics the resetting time follows equation below.

Figure. 6.3.3 - 60. Resetting characteristics for ANSI/IEEE IDMT.

$$t_r(G) = TMS\left[\frac{k_r}{1-\left(\frac{G}{G_S}\right)^{\propto}}\right]$$

The variables in the equation above are:

- tr(G) (seconds) = theoretical reset time with constant value of G
- k_r = contants characterizing the selected curve
- α = constant characterizing the selected curve
- G = measured value of the Fourier base harmonic of the phase currents
- G_S = pick-up setting value
- TMS = time dial setting / preset time multiplier

The parameters and operating curve types follow corresponding standards presented in the table below.

Table. 6.3.3 - 27. Parameters and operating curve types for the IDMT characteristics.

Curve family	Characteristics	k_r	α
IEC	NI (normally inverse)	User settable fixed reset time	
IEC	VI (very inverse)		
IEC	EI (extremely inverse)		
IEC	LTI (long time inverse)		
IEEE/ANSI	NI (normally inverse)	0.46	2
IEEE/ANSI	MI (moderately inverse)	4.85	2
IEEE/ANSI	VI (very inverse)	21.6	2
IEEE/ANSI	EI (extremely inverse)	29.6	2
IEEE/ANSI	LTI (long time inverse)	4.6	2
IEEE/ANSI	LTVI (long time, very inverse)	13.46	2
IEEE/ANSI	LTEI (long time, extremely inverse)	30	2

Table. 6.3.3 - 28. Setting parameters of the time overcurrent function.

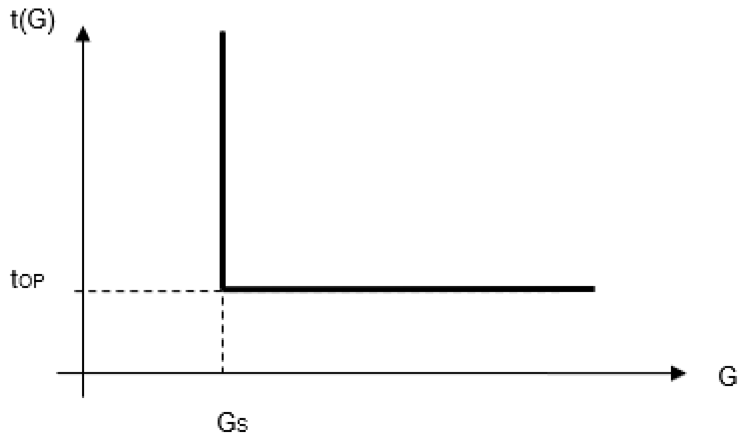
Parameter	Setting value / range	Step	Default	Description
Operation	Off DefinitTime IEC Inv IEC VeryInv IEC ExtInv IEC LongInv ANSI Inv ANSI ModInv ANSI VeryInv ANSI ExtInv ANSI LongInv ANSI LongVeryInv ANSI LongExtInv	-	DefinitTime	Operating mode selection of the function. Can be disabled, Definite time or IDMT operation based IEC or ANSI/IEEE standards.
Start current	5…400 %In	1 %In	200 %In	Pick-up current setting of the function.
Min Delay	0…60 000 ms	1 ms	100 ms	Minimum operating delay setting for the IDMT characteristics.
Definite delay time	0…60 000 ms	1 ms	100 ms	Definite time operating delay setting.This parameter is not in use when IDMT characteristics is selected for the operation.

Parameter	Setting value / range	Step	Default	Description
Reset delay	0…60 000 ms	1 ms	100 ms	Settable reset delay for definite time function and IEC IDMT operating characteristics. This parameter is in use with definite time and IEC IDMT characteristics.
Time Mult	0.05…999.0	0.01	-	Time multiplier / time dial setting of the IDMT operating characteristics. This parameter is not in use with definite time characteristics.

6.3.4 Residual time overcurrent protection (I0>; 50N/51N)

The residual definite time overcurrent protection function operates with definite time characteristics, using the RMS values of the fundamental Fourier component of the neutral or residual current (IN=3Io). In the figure below is presented the operating characteristics of the function.

$$t(G) = t_{OP} \text{ when } G > G_S$$



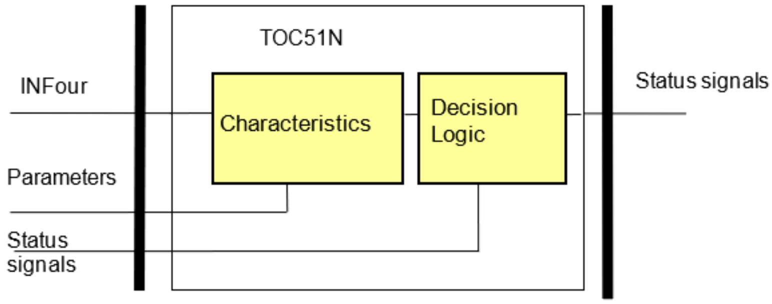
The variables in the image above are:

- t_{OP} (seconds) = theoretical operating time if $G>G_S$ (without additional time delay)
- G = measured value of the Fourier base harmonic of the residual current
- G_S = pick-up setting

The structure of the algorithm consists of following modules. Fourier calculation module calculates the RMS values of the Fourier components of the residual current. Characteristics module compares the Fourier basic harmonic components of the residual current into the setting value. Decision logic module generates the trip signal of the function.

In the figure below is presented the structure of the residual time overcurrent algorithm.

Figure. 6.3.4 - 61. Structure of the residual time overcurrent protection algorithm.



The algorithm generates a start signal based on the Fourier components of the residual current in case if the user set pick-up value is exceeded. Trip signal is generated after the set definite time delay.

The function includes a blocking signal input which can be configured by user from either IED internal binary signals or IED binary inputs through the programmable logic.

Table. 6.3.4 - 29. Setting parameters of the residual time overcurrent function.

Parameter	Setting value / Range	Step	Default	Description
Operation	Off DefinitTime IEC Inv IEC VeryInv IEC ExtInv IEC LongInv ANSI Inv ANSI ModInv ANSI VeryInv ANSI ExtInv ANSI LongInv ANSI LongVeryInv ANSI LongExtInv	-	DefinitTime	Operating mode selection of the function. Can be disabled, Definite time or IDMT operation based into IEC or ANSI/IEEE standards.
Start current	1…200 %In	1 %In	50 %In	Pick-up current setting of the function.
Min Delay	0…60 000 ms	1 ms	100 ms	Minimum operating delay setting for the IDMT characteristics.
Definite delay time	0…60 000 ms	1 ms	100 ms	Definite time operating delay setting. This parameter is not in use when IDMT characteristics is selected for the operation.
Reset time	0…60 000 ms	1 ms	100 ms	Settable reset delay for definite time function and IEC IDMT operating characteristics. This parameter is in use with definite time and IEC IDMT characteristics.
Time Mult	0.05…999.0	0.01	1.00	Time multiplier / time dial setting of the IDMT operating characteristics. This parameter is not in use with definite time characteristics.

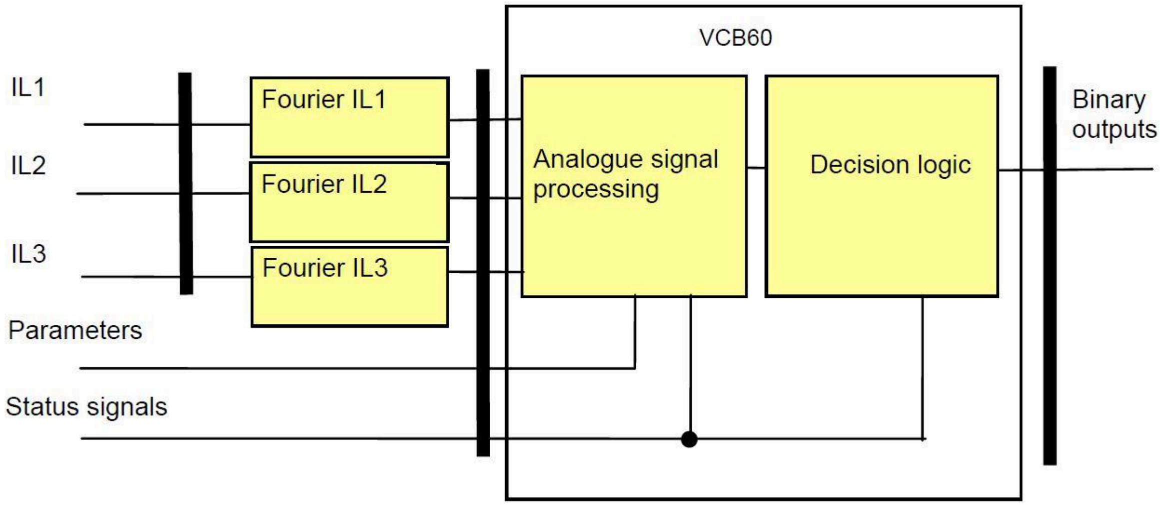
6.3.5 Current unbalance protection (60)

The current unbalance protection function can be applied to detect unexpected asymmetry in current measurement.

The applied method selects maximum and minimum phase currents (fundamental Fourier components). If the difference between them is above the setting limit, the function generates a start signal.

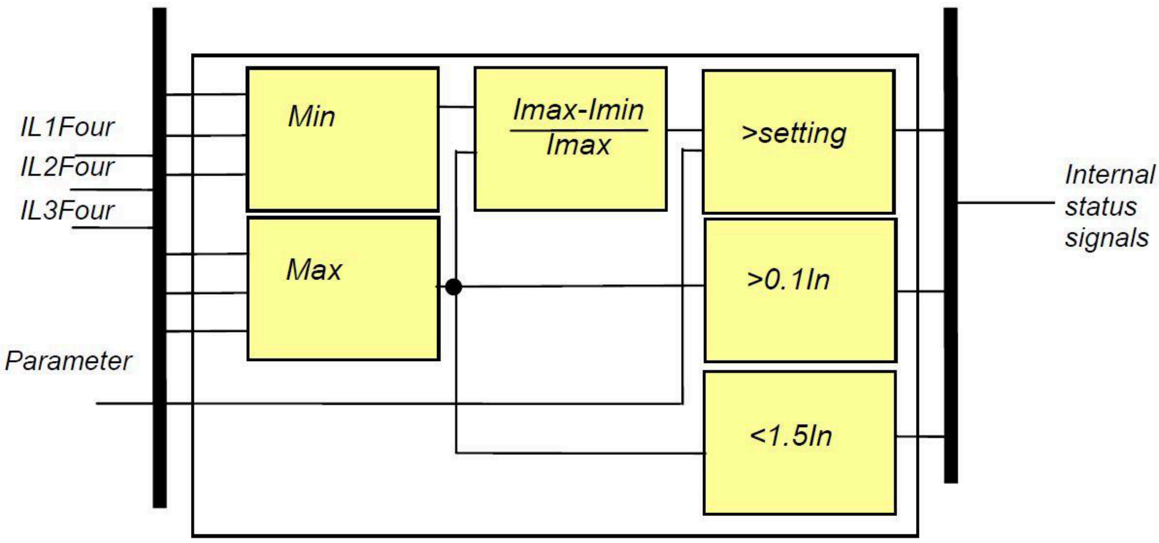
Structure of the current unbalance protection function is presented in the figure below

Figure. 6.3.5 - 62. The structure of the current unbalance protection algorithm.



The analogue signal processing principal scheme is presented in the figure below.

Figure. 6.3.5 - 63. Analogue signal processing for the current unbalance function.



The signal processing compares the difference between measured current magnitudes. If the measured relative difference between the minimum and maximum current is higher than the setting value the function generates a trip command. For stage to be operational the measured current level has to be in range of 10 % to 150 % of the nominal current. This precondition prevents the stage from operating in case of very low load and during other faults like shor tcircuit or earth faults.

The function can be disabled by parameter setting, and by an input signal programmed by the user.

The trip command is generated after the set defined time delay.

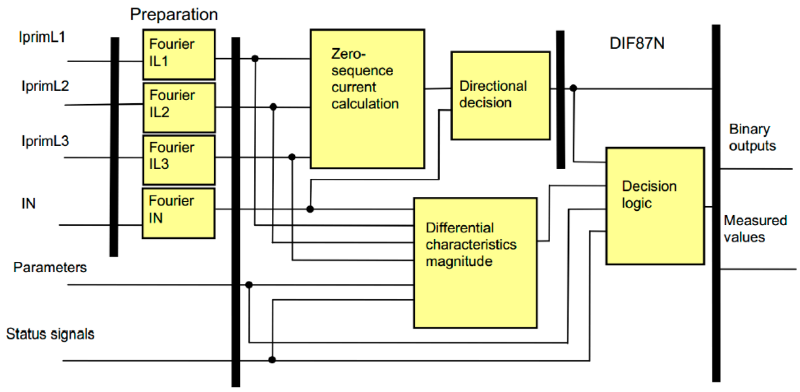
Table. 6.3.5 - 30. Setting parameters of the current unbalance function.

Parameter	Setting value / range	Step	Default	Description
Operation	On Off	-	On	Selection for the function enabled or disabled.
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either "Start" signal alone or both "Start" and after set time delay "Trip" signal.
Start current	10…90 %	1 %	50 %	Pick up setting of the current unbalance. Setting is the maximum allowed difference in between of the min and max phase currents.
Time delay	0…60 000 ms	1 ms	1 000 ms	Operating time delay setting for the "Trip" signal from the "Start" signal.

6.3.6 Restricted earth fault protection

The restricted earth-fault protection function is basically a low-impedance differential protection function based on zero sequence current components. It can be applied to transformers with grounded neutral. The function compares the measured neutral current and the calculated zero sequence current component of the phase currents and generates a trip command if the difference of these currents is above the characteristics. Restricted earth fault can be applied to both HV and LV side with 2 stages of the function.

Figure. 6.3.6 - 64. Structure of the restricted earth fault protection algorithm.



The inputs for the preparation are the sampled values of three primary phase currents, the sampled value of the neutral current. The inputs for the DIF87N function are:

- the RMS values of the fundamental Fourier components of the phase currents
- the RMS values of the fundamental Fourier components of the neutral current
- parameters
- status signal.

The outputs of the preparation are the RMS values of the fundamental Fourier components of the phase currents and that of the neutral current. The outputs of the DIF87N function are:

- the binary output status signal
- the measured values for displaying.

The software modules of the differential protection function:

- Fourier calculations
  These modules calculate the basic Fourier current components of the phase currents and that of the neutral current individually. These modules belong to the preparatory phase.
- Zero sequence current calculation
  This module calculates the zero sequence current components based on the Fourier components of the phase currents. These modules belong to the preparatory phase.
- Directional decision
  This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence components of the high fault currents in the phases, this decision improves the stability of the function.
- Differential characteristics
  This module performs the necessary calculations for the evaluation of the “percentage differential characteristics” and decides if the differential current is above the characteristic curve of the differential protection function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is needed for the decision logic.
- Decision logic
  The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function. The following description explains the details of the individual components.

Directional decision

This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence component of the high fault currents in the phases, this decision improves the stability of the function.

For the directional decision, the positive directions are drawn in following figure. In this system, if the angle between the calculated zero sequence current 3Io and the measured neutral current IN is out of the range of ±90 degrees, then the restricted earth fault protection can be blocked, the status signal (Dir.element Start) is set to TRUE value. The blocking is decided in the decision logic of the function, using the binary parameter.

Figure. 6.3.6 - 65. The positive directions of the currents.

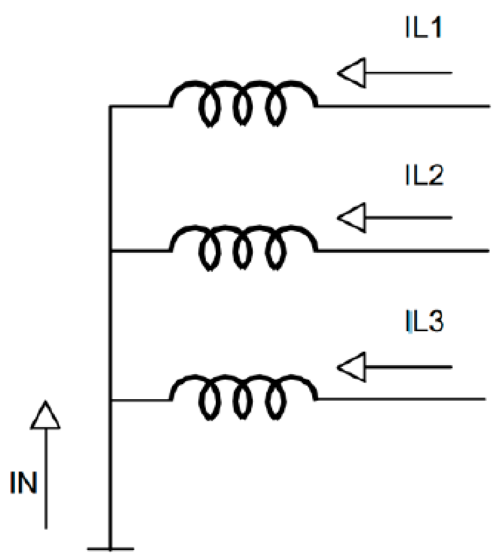
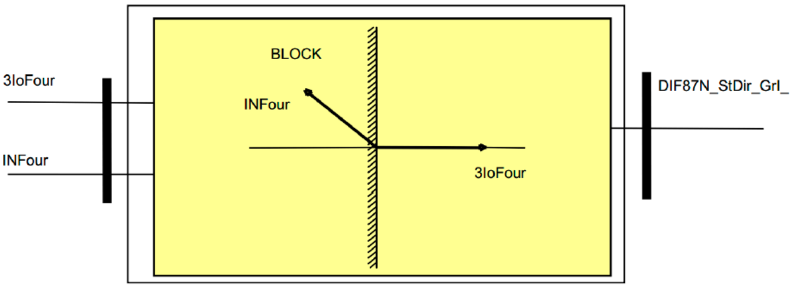


Figure. 6.3.6 - 66. Principal scheme of directional decision.



Zero sequence differential characteristics

This module performs the necessary calculations for the evaluation of the "percentage differential characteristics", and decides if the differential current is above the characteristic curve of the zero sequence differential protection function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is processed in the decision logic.

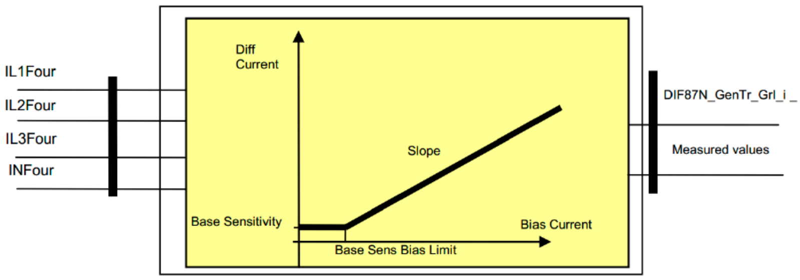
The differential current is calculated using the following formula:

Diff Current = IL1Four + IL2Four + IL3Four + INFour

The restraint current is calculated using the following formula:

Bias Current = MAX(IL1Four, IL2Four, IL3Four, INFour)

Figure. 6.3.6 - 67. Zero sequence differential protection characteristics.



The restricted earth-fault protection function generates a trip signal if the differential current as the function of the bias current is above the differential characteristic lines and the function is not blocked and the operation of the function is enabled by parameter setting. Blocking can be caused by the directional decision if it is enabled by parameter setting and the angle of the currents is in the blocking area or the user has composed a blocking graphic equation, and the conditions result a TRUE value for the blocking.

Setting parameters

Table. 6.3.6 - 31. Setting parameters of the restricted earth fault protection function.

Parameter	Setting value/range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection of the function.

Parameter	Setting value/range	Step	Default	Description
Directional check	Off On	-	On	Enabling the directional checking of the measured and calculated zero sequence currents.
TR Primary	20…500 %	1 %	100 %	Phase current CT compensation.
TR neutral	100…1 000 %	1 %	500 %	Neutral current CT compensation.
Base sensitivity	10…50 %	1 %	30 %	Basic pick-up setting of the function.
Second part	50…100 %	1 %	70 %	Slope of the second section of the characteristics.
Break point	100…200 %	1 %	125 %	Break point of the characteristics line.

6.3.7 Circuit breaker failure protection (CBFP; 50BF/52BF)

After a protection function generates a trip command, it is expected that the circuit breaker opens and/or the fault current drops below the pre-defined normal level. If not, then an additional trip command must be generated for all backup circuit breakers to clear the fault. At the same time, if required, a repeated trip command can be generated to the circuit breaker(s) which are expected to open. The breaker failure protection function can be applied to perform this task.

The starting signal of the breaker failure protection function is usually the trip command of any other protection function defined by the user. Dedicated timers start at the rising edge of the start signals, one for the backup trip command and one for the repeated trip command, separately for operation in the individual phases.

During the running time of the timers the function optionally monitors the currents, the closed state of the circuit breakers or both, according to the user's choice. When operation is based on current the set binary inputs indicating the status of the circuit breaker poles have no effect. If the operation is based on circuit breaker status the current limit values “Start current Ph” and “Start current N” have no effect on operation.

The breaker failure protection function resets only if all conditions for faultless state are fulfilled. If at the end of the running time of the backup timer the currents do not drop below the pre-defined level, and/or the monitored circuit breaker is still in closed position, then a backup trip command is generated in the phase(s) where the timer(s) run off.

The time delay is defined using the parameter “Backup Time Delay”. If repeated trip command is to be generated for the circuit breakers that are expected to open, then the enumerated parameter “Retrip” must be set to “On”. In this case, at the end of the timer(s) the delay of which is set by the timer parameter “Retrip Time Delay”, a repeated trip command is also generated. The pulse duration of the trip command is shall the time defined by setting the parameter “Pulse length”. The breaker failure protection function can be enabled or disabled by setting the parameter “Operation” to “Off”.

Dynamic blocking is possible using the binary input “Block”. The conditions can be programmed by the user.

Figure. 6.3.7 - 68. Operation logic of the CBFP function.

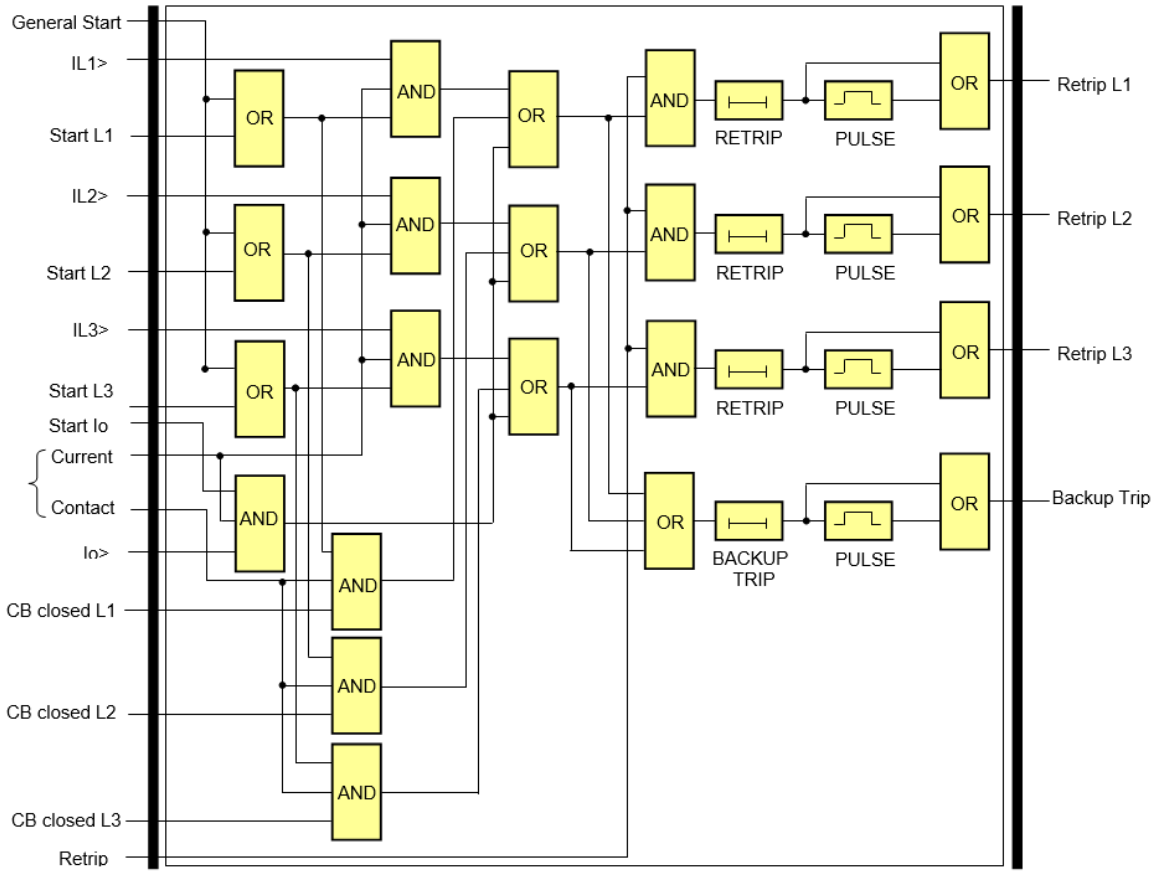


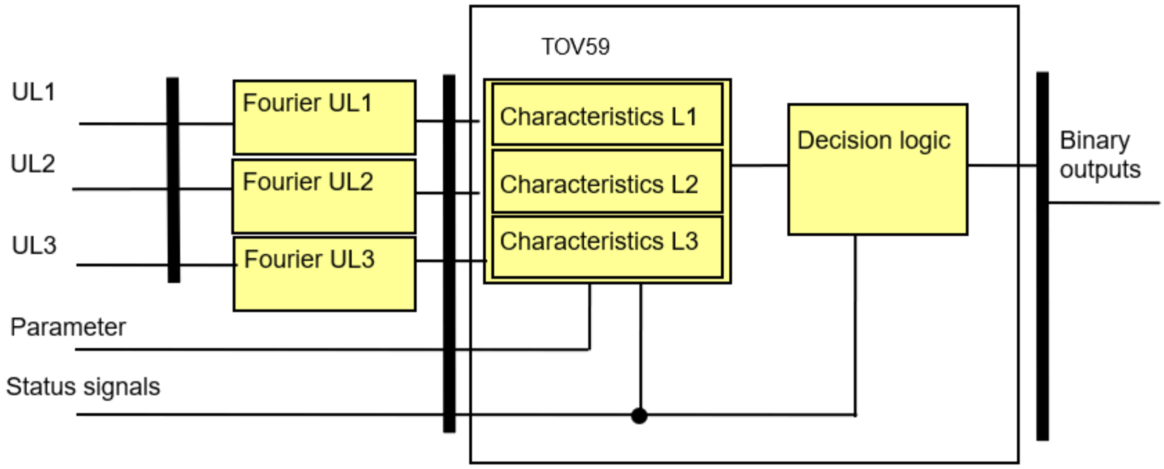
Table. 6.3.7 - 32. Setting parameters of the CBFP function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off Current Contact Current/ Contact	-	Current	Operating mode selection for the function. Operation can be either disabled “Off” or monitoring either measured current or contact status or both current and contact status.
Start current Ph	20…200 %	1 %	30 %	Pick-up current for the phase current monitoring.
Start current N	10…200 %	1 %	30 %	Pick-up current for the residual current monitoring.
Backup Time Delay	60…1 000 ms	1 ms	200 ms	Time delay for CBFP tripping command for the back-up breakers from the pick-up of the CBFP function monitoring.
Pulse length	0…60 000 ms	1 ms	100 ms	CBFP pulse length setting.

6.3.8 Overvoltage protection (U>; 59)

The overvoltage protection function measures three phase to ground voltages. If any of the measured voltages is above the pick-up setting, a start signal is generated for the phases individually.

Figure. 6.3.8 - 69. The principal structure of the overvoltage function.



The general start signal is set active if the voltage in any of the three measured voltages is above the level defined by pick-up setting value. The function generates a trip command after the definite time delay has elapsed.

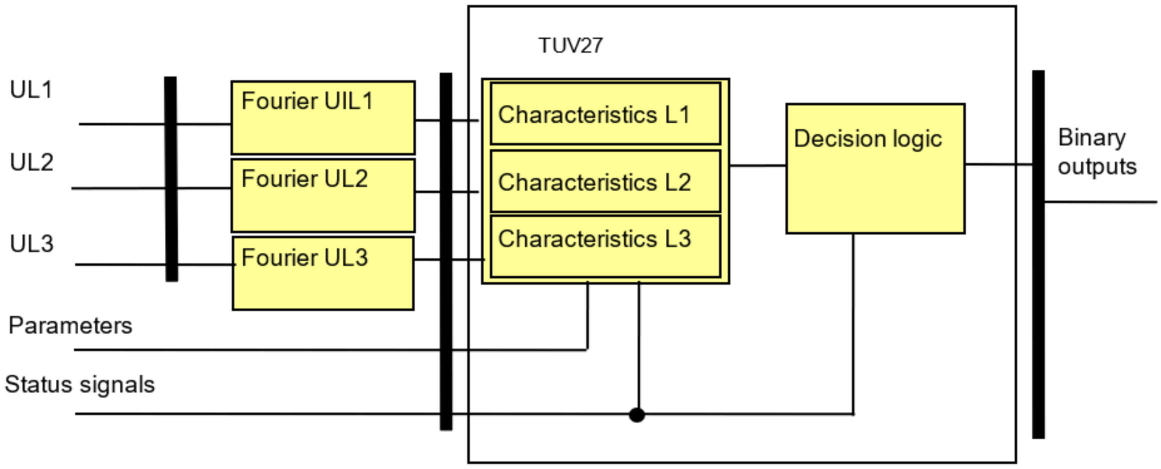
Table. 6.3.8 - 33.

Parameter	Setting value / range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection for the function. Operation can be either enabled "On" or disabled "Off".
Start voltage	30…130 %	1 %	63 %	Voltage pick-up setting
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone or both “Start” and after set time delay “Trip” signal.
Reset ratio	1…10 %	1 %	5 %	Overvoltage protection reset ratio.
Time delay	0…60 000 ms	1 ms	100 ms	Operating time delay setting for the “Trip” signal from the “Start” signal.

6.3.9 Undervoltage protection (U<; 27)

The undervoltage protection function measures three voltages. If any of them is below the set pick-up value and above the defined minimum level, then a start signal is generated for the phases individually.

Figure. 6.3.9 - 70. The principal structure of the undervoltage function.



The general start signal is set active if the voltage of any of the three measured voltages is below the level defined by pick-up setting value. The function generates a trip command after the definite time delay has elapsed.

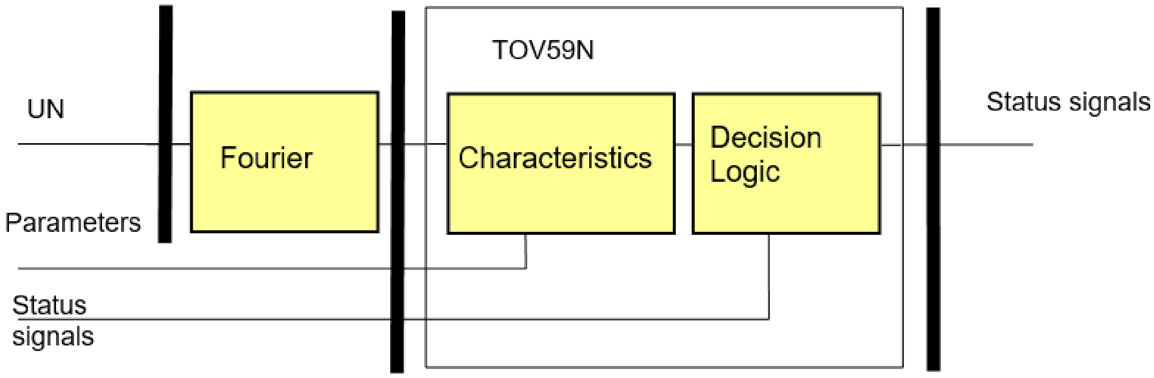
Table. 6.3.9 - 34. Setting parameters of the undervoltage function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off 1 out of 3 2 out of 3 All	-	1 out of 3	Operating mode selection for the function. Operation can be either disabled “Off” or the operating mode can be selected to monitor single phase undervoltage, two phases undervoltage or all phases undervoltage condition.
Start voltage	30…130 %	1 %	90 %	Voltage pick-up setting
Block voltage	0…20 %	1 %	10 %	Undervoltage blocking setting. This setting prevents the function from starting in undervoltage condition which is caused for example from opened breaker.
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone or both “Start” and after set time delay “Trip” signal.
Reset ratio	1…10 %	1 %	5 %	Undervoltage protection reset ratio
Time delay	0…60 000 ms	1 ms	100 ms	Operating time delay setting for the "Trip" signal from the "Start" signal.

6.3.10 Residual overvoltage protection (U0>; 59N)

The residual definite time overvoltage protection function operates according to definite time characteristics, using the RMS values of the fundamental Fourier component of the zero sequence voltage (UN=3Uo).

Figure. 6.3.10 - 71. The principal structure of the residual overvoltage function.



The general start signal is set active if the measured residual voltage is above the level defined by pick-up setting value. The function generates a trip command after the set definite time delay has elapsed.

Table. 6.3.10 - 35. Setting parameters of the undervoltage function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection for the function. Operation can be either enabled "On" or disabled “Off”.
Start voltage	2…60 %	1 %	30 %	Voltage pick-up setting
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone or both “Start” and after set time delay “Trip” signal.
Reset ratio	1…10 %	1 %	5 %	Residual overvoltage protection reset ratio
Time delay	0…60 000 ms	1 ms	100 ms	Operating time delay setting for the "Trip" signal from the "Start" signal.

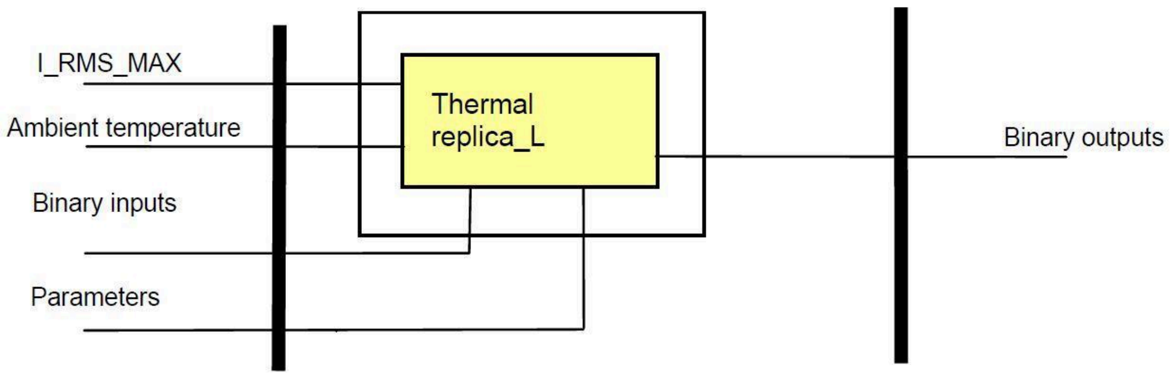
6.3.11 Thermal overload protection (T>; 49)

The line thermal protection measures basically the three sampled phase currents. TRMS values of each phase currents are calculated including harmonic components up to 10th harmonic, and the temperature calculation is based on the highest TRMS value of the compared three phase currents.

The basis of the temperature calculation is the step-by-step solution of the thermal differential equation. This method provides “overtemperature”, i.e. the temperature above the ambient temperature. Accordingly the final temperature of the protected object is the sum of the calculated “overtemperature” and the ambient temperature.

The ambient temperature can be set manually. If the calculated temperature (calculated “overtemperature”+ambient temperature) is above the threshold values, status signals are generated: Alarm temperature, Trip temperature and Unlock/restart inhibit temperature.

Figure. 6.3.11 - 72. The principal structure of the thermal overload function.



In the figure above is presented the principal structure of the thermal overload function. Theinputs of the function are the maximum of TRMS values of the phase currents, ambienttemperature setting, binary input status signals and setting parameters. Function outputsbinary signals for Alarm, Trip pulse and Trip with restart inhibit.

The thermal replica of the function follows the following equation.

$$H(t) = \frac{\theta(t)}{\theta_n} = \frac{I^2}{I_n^2}\left(1 - e^{-\frac{t}{T}}\right) + \frac{\theta_0}{\theta_n} e^{-\frac{t}{T}}$$

The equation's variables are as follows:

- H(t) = thermal level of the heated object; the temperature as a percentage of θ_n reference temperature
- θ_n = reference temperature above the ambient temperature, which can be measured in steady state in case of a continuous I_n refrence current
- I_n = reference current (can be considered as the nomincal current of the heated object); if the current flows continuously then the reference temperature can be measured in steady state
- I = measured current
- θ_0 = starting temperature
- T = heating time constant.

Table. 6.3.11 - 36. Setting parameters of the thermal overload function.

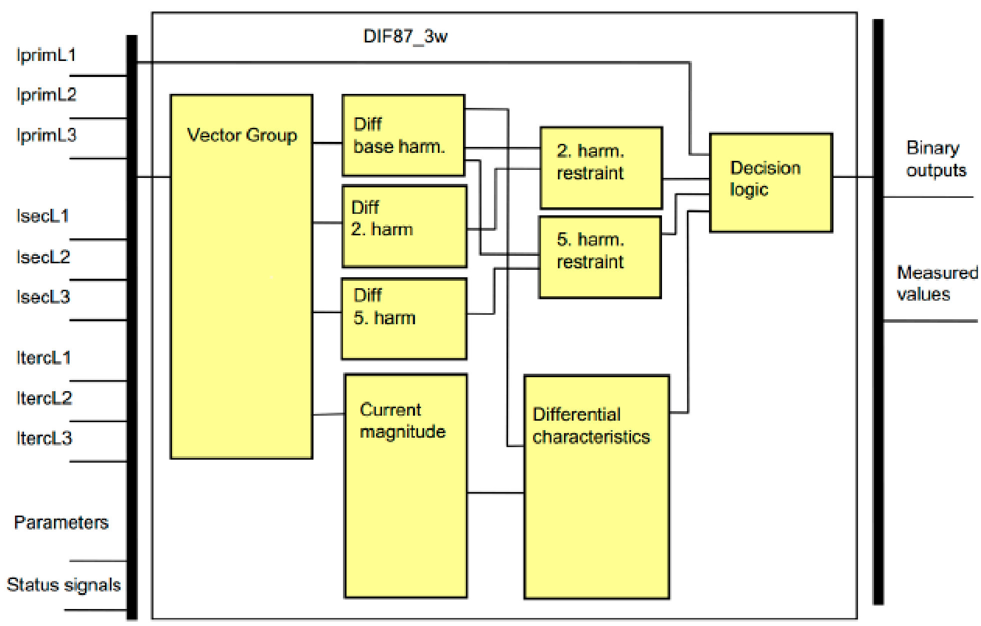
Parameter	Setting value / range	Step	Default	Description
Operation	Off Pulsed Locked	-	Pulsed	Operating mode selection. "Pulsed" operation means that the function gives tripping pulse when the calculated thermal load exceeds the set thermal load. "Locked" means that the trip signal releases when the calculated thermal load is cooled under the set Unlock temperature limit after the tripping.
Alarm temperature	60…200 deg	1 deg	80 deg	Temperature setting for the alarming of the overloading. When the calculated temperature exceeds the set alarm limit function issues an alarm signal.
Trip temperature	60…200 deg	1 deg	100 deg	Temperature setting for the tripping of the overloading. When the calculated temperature exceeds the set alarm limit function issues a trip signal.

Parameter	Setting value / range	Step	Default	Description
Rated temperature	60…200 deg	1 deg	100 deg	Rated temperature of the protected object.
Base temperature	0…40 deg	1 deg	40 deg	Rated ambient temperature of the device related to allowed temperature rise.
Unlock temperature	20…200 deg	1 deg	60 deg	Releasing of the function generated trip signal when the calculated thermal load is cooled under this setting. Restart inhibit release limit.
Ambient temperature	0…40 deg	1 deg	25 deg	Setting of the ambient temperature of the protected device.
Startup Term	0…60 %	1 %	0 %	On device restart starting used thermal load setting. When the device is restarted the thermal protection function will start calculating the thermal replica from this starting value.
Rated LoadCurrent	20…150 %	1 %	100 %	The rated nominal load of the protected device.
Time constant	1…999 min	1 min	10 min	Heating time constant of the protected device.

6.3.12 Transformer differential protection (87T)

The differential protection function provides main protection for transformers, generators or large motors, but it can also be applied for overhead lines and cables of solidly grounded networks or for the protection of any combination of the aforementioned protected objects. Version DIF87_3w can be applied to protect three-winding transformers. The simpler version DIF87_2w does not process analogue inputs from the tertiary side. This chapter describes the three-winding transformer version but it also refers to necessary changes in application with transformers of two sides only.

Figure. 6.3.12 - 73. Structure of the differential protection algorithm.



The inputs of the function are:

- Sampled values of three primary side phase currents
- Sampled values of three secondary side phase currents
- Sampled values of three tertiary side phase currents (in DIF87_3w version only AQ-T393)
- Setting parameters
- Status signals.

The outputs of the function are:

- Binary output status signals
- Measured values for displaying.

The software modules of the differential protection function:

- Vector group
  This module compensates the phase shift and turns ratio of the transformer. The results of this calculation are the “sampled values” of the phase-shifted phase currents for all three (two) sides of the transformer and those of the three differential currents.
- Diff base harm
  This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.
- Diff 2. harm
  This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.
- Diff 5. harm
  This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.
- 2. harm. restraint
  The differential current can be high during the transients of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case, the second harmonic content of the differential current is applied in this module to disable the operation of the differential protection function. The result of this calculation is needed for the decision logic.
- 5. harm. restraint
  The differential current can be high if the transformer is over-excited by a connected generator, due to the current distortion caused by the transformer iron core symmetric saturation. In this case, the fifth harmonic content of the differential current is applied in this module to disable the operation of the differential protection function. The result of this calculation is needed for the decision logic.
- Current magnitude
  This module calculates the magnitude of the phase-shifted phase currents and that of the differential currents. The result of this calculation is needed for the evaluation of differential characteristics.
- Differential characteristics
  This module performs the necessary calculations for the evaluation of the “percentage differential characteristics”. The result of this calculation is needed for the decision logic.
- Decision logic
  The decision logic module decides if the differential current of the individual phases is above the characteristic curve of the differential protection function. This curve is the function of the restraint current, which is calculated based on the magnitude of the phase-shifted phase currents. This module calculates the second and fifth harmonic ratios of the differential current relative to the basic harmonic content. The result can restrain the operation of the differential protection function. The high-speed overcurrent protection function based on the differential currents is also performed in this module.

Vector shift compensation

The three-phase power transformers transform the primary current to the secondary side according to the turns ratio and the vector group of the transformers. The Y (star), D (delta) or Z (zig-zag) connection of the three phase coils on the primary and secondary sides causes the vector shift of the currents.

The conventional electromechanical or static electronic devices of the differential protection compensate the vector shift with the appropriate connection of the current transformer coils. The numerical differential protection function applies matrix transformation of the directly measured currents of one side of the transformer to match them with the currents of the other side. In AQ-T300 series transformer differential protection the „Vector_group" software module calculates the matrix transformation and turns ratio matching. In this case, the target of the matrix transformation is the delta (D) side.

The Y-connected current transformers on the delta side of the transformer do not shift the currents flowing out of the transformer. The delta-connected current transformers on the Y side of the transformer, however, result in a phase shift. This means that the Y-side currents are shifted according to the vector group of the transformer to match the delta-side currents.

Additionally, the delta connection of the current transformers eliminates the zero sequence current component flowing on the grounded Y side of the transformer. As no zero sequence current can be detected on the delta side, this compensation is essential for the correct operation of the differential protection. If a phase-to-ground fault occurs on the Y side of the transformer, then zero sequence current flows on the grounded Y side while no out-flowing zero sequence current can be detected on the delta side. Without the elimination of the zero sequence current component, the differential protection generates a trip command in case of an external ground fault. If, however, the connection group of the current transformers on the Y side is delta, no zero sequence current flows out of the group. Thus the problem of zero sequence current elimination in case of an external ground fault is solved.

The numerical differential protection function applies numerical matrix transformation for modeling the delta connection of the current transformers. In practice, it means cyclical subtraction of the phase currents. In the vector shift compensation the sampled rst currents of the primary side (I1r, I1s, I1t) and those of the secondary side ((I2r, I2s, I2t)) are transformed to (RSTshift) values of both sides respectively, using matrix transformation. The method of transformation is defined by the „Code" parameter identifying the transformer vector group connection.

The table below summarizes the method of transformation, broken down by the connection group of the transformers with two voltage levels. The tertiary side, if any – related to the primary – is processed similarly:

Table. 6.3.12 - 37. Vector shift compensation with transformation to the delta side.

Tr. Conn. Group	Code	Transformation of the primary side currents	Transformation of the secondary side currents
Dy1	00	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dy5	01	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$

Tr. Conn. Group	Code	Transformation of the primary side currents	Transformation of the secondary side currents
Dy7	02	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dy11	03	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dd0	04	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dd6	05	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz0	06	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & 1 \\ 1 & 2 & -1 \\ -1 & 1 & 2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz2	07	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz4	08	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz6	09	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz8	10	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Dz10	11	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yy0	12	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$

Tr. Conn. Group	Code	Transformation of the primary side currents	Transformation of the secondary side currents
Yy6	13	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yd1	14	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yd5	15	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yd7	16	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yd11	17	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yz1	18	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yz5	19	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yz7	20	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$
Yz11	21	$\begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I1r \\ I1s \\ I1t \end{bmatrix}$	$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$

The differential currents are calculated using the (RSTshift) values and the (TR primary) and (TR secondary) parameters, defined by the turns ratio of the transformer and that of the current transformers, resulting in the currents marked with an apostrophe ('). The tertiary side is processed similarly. (The positive direction of the currents is flowing IN on both sides.)

$$\begin{bmatrix} IdR \\ IdS \\ IdT \end{bmatrix} = \begin{bmatrix} I1Rshift' \\ I1Sshift' \\ I1Tshift' \end{bmatrix} + \begin{bmatrix} I2Rshift' \\ I2Sshift' \\ I2Tshift' \end{bmatrix} = \frac{100}{TR\_primary} \begin{bmatrix} I1Rshift \\ I1Sshift \\ I1Tshift \end{bmatrix} + \frac{100}{TR\_secondary} \begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix}$$

The current measuring software modules process these momentary values of the differential currents and calculate values that are proportional to the RMS values.

Operation with the zero sequence current in case of a phase-to-ground fault on the delta side

On the secondary side of a high voltage /medium voltage transformer which is connected in delta on the medium voltage side, an additional neutral grounding transformer is applied. Between the neutral point of this grounding transformer and the ground either a grounding resistor is connected to limit the single phase-to-ground fault currents below 100 A – 200 A or with a Petersen coil, which limits the single-phase fault currents to a few Amps. In these cases, there are two locations for the current transformers on the delta side to supply the differential protection.

In one case, the neutral grounding transformer is located inside the protected zone of the differential, in the other case the neutral grounding transformer is outside the protected zone. If the neutral grounding transformer is in the protected zone, then the current distribution depends on the location of the supplying generator. In these cases, for the correct operation of the differential protection (if the operating characteristic lines are set to be sensitive) the subtraction of the zero sequence current is needed. This additional transformation „moves" the measuring location to the point („Y") where no zero sequence current can flow, so these transformed currents do not include the zero sequence current of the neutral grounding transformer.

Harmonic analysis of the differential currents

The differential current can be high during the transients of transformer energizing due to the current distortion caused by the transformer iron core asymmetrical saturation. In this case, the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can be high in case of the over-excitation of the transformer due to the current distortion caused by the transformer iron core symmetrical saturation. In this case, the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of three individual software modules:

- Diff base harm
  This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.
- Diff 2. harm
  This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.
- Diff 5. harm
  This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.

The harmonic restraint decision (2. harmonic restraint) and (5. harmonic restraint)

The differential current can be high during transformer energizing due to the current distortion caused by the transformer iron core asymmetrical saturation. In this case, the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can be high in case of the over-excitation of the transformer due to the current distortion caused by the transformer iron core symmetrical saturation. In this case, the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of two sub-blocks, one for the second harmonic decision and one for the fifth harmonic decision. Each sub-block includes three individual software modules for the phases.

The software modules evaluate the harmonic content relative to the basic harmonic component of the differential currents and compare the result with the parameter values set for the second and fifth harmonic. If the content is high, then the assigned status signal is set to "true" value. If the duration of the active status is at least 25 ms, then the resetting of the status signal is delayed by an additional 15 ms.

The evaluation of the differential characteristics

This module evaluates the differential characteristics. It compares the magnitudes of the differential currents and those of the restraint currents. The restraint currents are calculated using the following formulas:

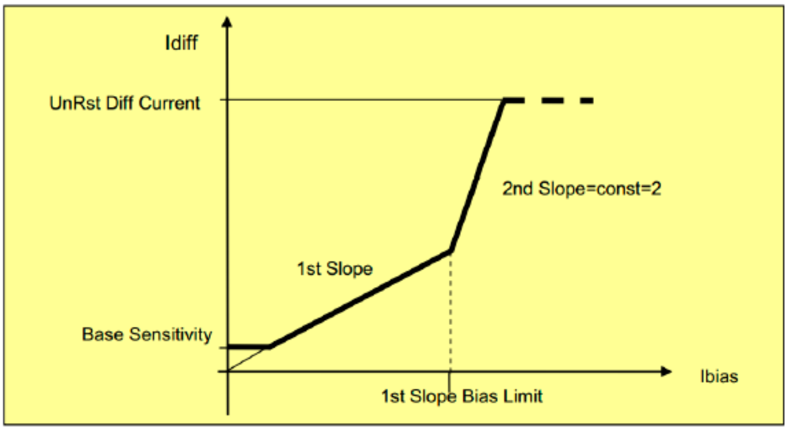
$$M\_IbiasR = \frac{M\_I1Rshift' + M\_I2Rshift' + M\_I3Rshift''}{2}$$

$$M\_IbiasS = \frac{M\_I1Sshift' + M\_I2Sshift' + M\_I3Sshift''}{2}$$

$$M\_IbiasT = \frac{M\_I1Tshift' + M\_I2Tshift' + M\_I3Tshift''}{2}$$

Based on these values (generally denoted as "Ires") and the values of the differential current magnitudes (generally denoted as "Id"), the differential protection characteristics is shown in following figure.

Figure. 6.3.12 - 74. Differential characteristics.

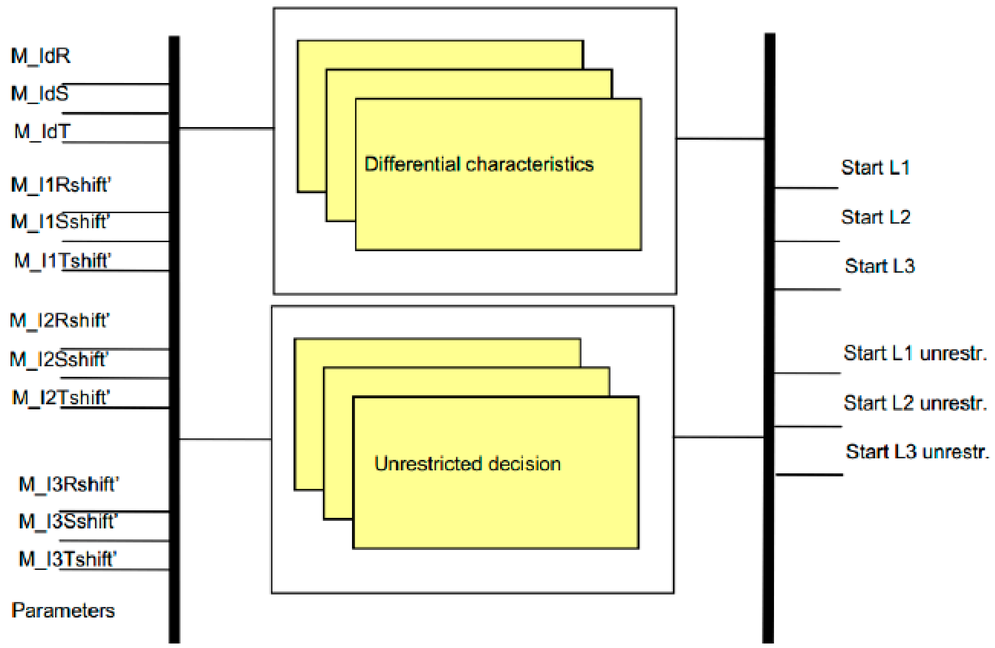


Additionally, separate status signals are set to "true" value if the differential currents in the individual phases are above the limit set by the dedicated parameter (see "Unrestricted differential function").

The unrestricted differential function

If the calculated differential current is very high, then the differential characteristic is not considered anymore because the separate status signals for the phases are set to "true" value if the differential currents in the individual phases are above the limit defined by parameter setting. The decisions of the phases are connected in an OR gate to result in the general start status signal.

Figure. 6.3.12 - 75. Operating principle of the current restraint and non-restraint characteristics.



Setting parameters

Table. 6.3.12 - 38. Setting parameters of the differential protection function.

Parameter	Setting value/range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection of the differential function.
Pri-Sec VGroup*	Dy1, Dy5, Dy7, Dy11 Dd0, Dd6 Dz0, Dz2, Dz4, Dz6, Dz8, Dz10 Yy0, Yy6 Yd1, Yd5, Yd7, Yd11 Yz1, Yz5, Yz7, Yz11	-	Dd0	Vector group selection of the transformer coils in primary-secondary relation.
Pri-Ter VGroup*	Dy1, Dy5, Dy7, Dy11 Dd0, Dd6 Dz0, Dz2, Dz4, Dz6, Dz8, Dz10 Yy0, Yy6 Yd1, Yd5, Yd7, Yd11 Yz1, Yz5, Yz7, Yz11	-	Dd0	Vector group selection of the transformer coils in primary-tertiary relation.
ZeroSequ.Elimination	True False	-	True	Selection of the zero sequence current elimination.
TR Primary comp. TR Secondary comp. TR Tertiary comp.	20…500 %	1 %	100 %	Parameters for the current magnitude compensation.
2nd Harm. Ratio	5…50 %	1 %	15 %	Parameter of the second harmonic restraint.

Parameter	Setting value/range	Step	Default	Description
5th Harm. Ratio	5…50 %	1 %	25 %	Parameter of the fifth harmonic restraint.
Base sensitivity	10…50 %	1 %	20 %	Basic pick-up setting for the current restraint differential characteristics.
1st Slope	10…50 %	1 %	20 %	First slope setting.
1st Slope Bias Limit	200…2 000 %	1 %	200 %	Second slope setting.
Unrestrained I-Diff	800…2 500 %	1 %	800 %	Non-restraint characteristics pick-up setting.

*) If the connection of the primary winding in the primary-secondary and primary-tertiary relations is selected in contradiction, then the protection function is automatically disabled and the function generates a warning signal.

Function	
Operating characteristic	2 breakpoint
Reset ratio	0.95
Characteristic accuracy	<2 %
Operate time, unrestrained	typically 20 ms
Reset time, unrestrained	typically 25 ms
Operate time, restrained	<35 ms
Reset time, restrained	<25 ms

Example setting calculation

Transformer data:

- Sn = 125 MVA
- U1/U2 = 132/11.5 kV/kV
- Yd11

Current transformer:

- CT1 = 600/1 A/A
- CT2 = 6 000/1 A/A

Rated currents of the transformer:

- I1np = 546 A (on the secondary side: I1n = 0.91 A)
- I2np = 627 A (on the secondary side: I2n = 1.05 A)

Setting parameters

TR Primary Comp = 91 %

(This is a free choice, giving the currents of the primary side current transformer's current, related to the rated current of the CT.)

TR Secondary Comp = 105 %

(This is a direct consequence of selecting TR primary; this is the current of the secondary side current transformer related to the rated current of the CT.)

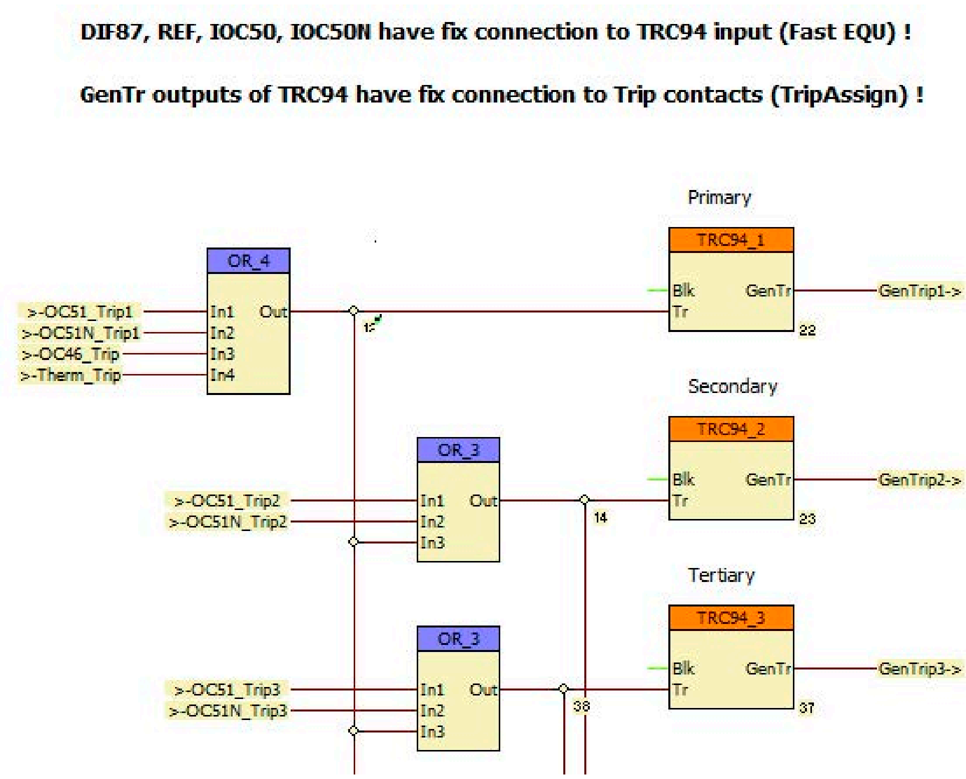
The code value of the transformer's connection group (Yd11):

Pri-Sec VGroup = Yd11

Fixed trip assignment into trip logic

To ensure fast tripping required from differential functions the trip signal always has a factory fixed connection to the TRC94 trip logic blocks. See the picture of logic mentioning this.

Figure. 6.3.12 - 76. Logic where the factory fixed connection of DIF87, REF, IOC50, IOC50N have fix connection to TRC94 blocks seen in the picture.



The tripping contacts for these TRC94 function blocks are defined in *Software configuration → Trip signals → Trip assignment*.

6.3.13 Overfrequency protection (f>; 81O)

The deviation of the frequency from the rated system frequency indicates unbalancebetween the generated power and the load demand. If the available generation is largecompared to the consumption by the load connected to the power system, then the systemfrequency is above the rated value.

The over-frequency protection function is usually applied to decrease generation to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of high frequency can be an indication of island operation. Accurate frequency measurement is also the criterion for the synchro-check and synchro-switch functions.

The frequency measurement is based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of the voltage input module. In some applications, the frequency is measured based on the weighted sum of the phase voltages. The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal.

For the confirmation of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value. The over-frequency protection function generates a start signal if at least five measured frequency values are above the preset level.

Table. 6.3.13 - 39. Setting parameters of the overfrequency protection function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection for the function. Operation can be either enabled "On" or disabled "Off".
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone or both “Start” and after set time delay “Trip” signal.
Start frequency	40.00…60.00 Hz	0.01 Hz	51 Hz	Pick-up setting of the function. When the measured frequency value exceeds the setting value function initiates "Start" signal.
Time delay	0…60 000 ms	1 ms	200 ms	Operating time delay setting for the “Trip” signal from the“Start” signal.

6.3.14 Underfrequency protection (f<; 81U)

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is small compared to the consumption by the load connected to the power system, then the system frequency is below the rated value.

The under-frequency protection function is usually applied to increase generation or for load shedding to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of low frequency can be an indication of island operation. Accurate frequency measurement is also the criterion for the synchro-check and synchro-switch functions.The frequency measurement is based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of the voltage input module. In some applications, the frequency is measured based on the weighted sum of the phase voltages. The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal.

For the confirmation of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value. The under-frequency protection function generates a start signal if at least five measured frequency values are below the setting value.

Table. 6.3.14 - 40. Setting parameters of the underfrequency protection function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection for the function. Operation can be either enabled "On" or disabled "Off".
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone orboth “Start” and after set time delay “Trip” signal.
Start frequency	40.00…60.00 Hz	0.01 Hz	49 Hz	Pick-up setting of the function. When the measured frequency value exceeds the setting value function initiates "Start" signal.
Time delay	0…60 000 ms	1 ms	200 ms	Operating time delay setting for the “Trip” signal from the“Start” signal.

6.3.15 Rate-of-change of frequency protection (fd/ft>/<; 81R)

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is small compared to the consumption by the load connected to the power system, then the system frequency is below the rated value. If the unbalance is large, then the frequency changes rapidly. The rate of change of frequency protection function is usually applied to reset the balance between generation and consumption to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of a high rate of change of frequency can be an indication of island operation. Accurate frequency measurement is also the criterion for the synchro-switch function.

The source for the rate of change of frequency calculation is an accurate frequency measurement. The frequency measurement is based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of the voltage input module. In some applications, the frequency is measured based on the weighted sum of the phase voltages. The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal.

For the confirmation of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value. The rate of change of frequency protection function generates a start signal if the df/dt value is above the setting vale. The rate of change of frequency is calculated as the difference of the frequency at the present sampling and at three cycles earlier.

Table. 6.3.15 - 41. Setting parameters of the rate-of-change of frequency function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off On	-	On	Operating mode selection for the function. Operation can be either enabled "On" or disabled "Off".
Start signal only	Activated Deactivated	-	Deactivated	Selection if the function issues either “Start” signal alone orboth “Start” and after set time delay “Trip” signal.
Start df/dt	–5…5 Hz/s	0.01 Hz/s	0.5 Hz/s	Pick-up setting of the function. When the measured frequency value exceeds the setting value function initiates "Start" signal.

Parameter	Setting value / range	Step	Default	Description
Time delay	0…60 000 ms	1 ms	200 ms	Operating time delay setting for the “Trip” signal from the“Start” signal.

6.3.16 Overexcitation (V/H>; 24)

The over excitation protection function is applied to protect generators and unit transformers against high flux values causing saturation of the iron cores and consequently high magnetizing currents.

The problem to be solved is as follows: The flux is the integrated value of the voltage:

$$\Phi(t) = \Phi_0 + \int_0^t u(t)dt$$

In steady state, this integral can be high if the area under the sinusoidal voltage-time function is large. Mathematically this means that in steady state the flux, as the integral of the sinusoidal voltage function, can be expressed as

$$\Phi(t) = k\frac{U}{f}cos\omega t$$

The peak value of the flux increases if the magnitude of the voltage increases, and/or the flux can be high if the duration of a period increases; this means that the frequency of the voltage decreases. That is, the flux is proportional to the peak value (or to the RMS value) of the voltage and inversely proportional to the frequency.

Note: the overexcitation protection function is intended to be applied near the generator, where the voltage is expected to be pure sinusoidal, without any distortion. Therefore, a continuous integration of the voltage and a simple peak detection algorithm can be applied.

The effect of high flux values is the symmetrical saturation of the iron core of the generator or that of the unit transformer. During saturation, the magnetizing current is high and distorted; high current peaks can be detected. The odd harmonic components of the current are of high magnitude and the RMS value of the current also increases. The high peak values of the currents generate high dynamic forces, the high RMS value causes overheating. During saturation, the flux leaves the iron core and high eddy currents are generated in the metallic part of the generator or transformer in which normally no current flows, and which is not designed to withstand overheating.

The frequency can deviate from the rated network frequency during start-up of the generator or at an unwanted disconnection of the load. In this case the generator is not connected to thenetwork and the frequency is not kept at a “constant” value. If the generator is excited in this state and the frequency is below the rated value, then the flux may increase above the tolerated value. Similar problems may occur in distributed generating stations in case of island operation.

The overexcitation protection is designed to prevent this long-term overexcited state.The flux is calculated continuously as the integral of the voltage. In case of the supposed sinusoidal voltage, the shape of the integrated flux will be sinusoidal too, the frequency of which is identical with that of the voltage. The magnitude of the flux can be found by searching for the maximum and the minimum values of the sinusoid.

The magnitude can be calculated if at least one positive and one negative peak value have been found, and the function starts if the calculated flux magnitude is above the setting value. Accordingly, the starting delay of the function depends on the frequency: if the frequency is low, more time is needed to reach the opposite peak value. In case of energizing, the time to find the first peak depends on the starting phase angle of the sinusoidal flux. If the voltage is increased continuously by increasing the excitation of the generator, this time delay cannot be measured.

Operating characteristics

The most harmful effect of the overexcited state is unwanted overheating. As the heating effect of the distorted current is not directly proportional to the flux value, the applied characteristic is of inverse type (so called IEEE type): If the overexcitation increases, the operating time decreases. To meet the requirements of application, a definite-time characteristic is also offered in this protection function as an alternative.The supervised quantity is the calculated U/f value as a percentage of the nominal values (index N):

$$G = \frac{U/f}{U_N/f_N} 100[\%] = \frac{U/U_N}{f/f_N} 100[\%]$$

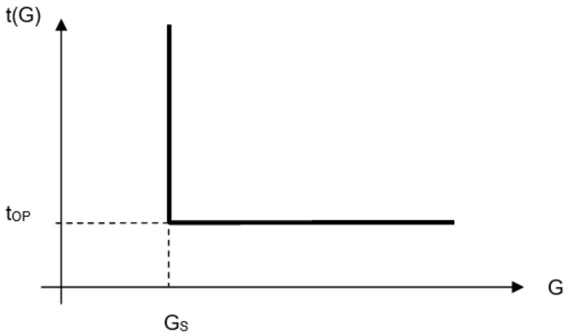
The over-dimensioning of generators in this respect is usually about 5%, that of the transformer about 10%, but for unit transformers this factor can be even higher.

At start-up of the function, the protection generates a warning signal aimed to inform the controller to decrease the excitation. If the time delay determined by the parameter values of the selected characteristics expires, the function generates a trip command to decrease or to switch off the excitation and the generator.

Definite time characteristics

Operate time

Figure. 6.3.16 - 77. Overexcitation independent time characteristic.



where:

$t(G) = t_{OP}$ (when $G>G_S$)

t_{OP} (seconds) = the theoretical operating time $G>G_S$, fix, according to the parameter setting (VPH24_MinDel_TPar_, Min. Time Delay)

G = the measured value of the characteristic quantity; this is the U/f peak value as a percentage of the rated U_N/f_N value

G_S = the setting value of the characteristic quantity (VPH24_EmaxCont_IPar_, Start U/f LowSet); this is the U_{set}/f_{set} peak value as a percentage of the rated U_N/f_N value

Reset time

t(G) = $t_{Drop\text{-}off}$ (when G<0.95*G_S)

where:

$t_{drop\text{-}off}$ (seconds) = the drop-off time if G<0.95*G_S, fix value

IEEE standard dependent time characteristics

Operating time

"IEEE square law"

$$t = \frac{0.18 * TMS}{\left(\frac{U/f}{U_N/f_N} - \frac{U_{set}/f_{set}}{U_N/f_N}\right)^2} = \frac{0.18 * TMS}{(G - G_S)^2}$$

where:

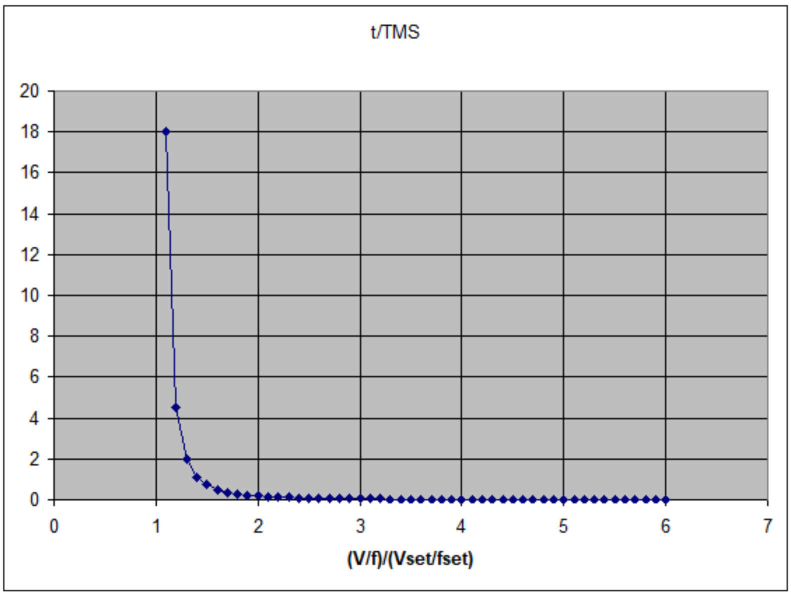
TMS = 1…60, time multiplier setting

U/f = flux value calculated at the measured voltage and frequency

U_N/f_N = flux at rated voltage and rated frequency

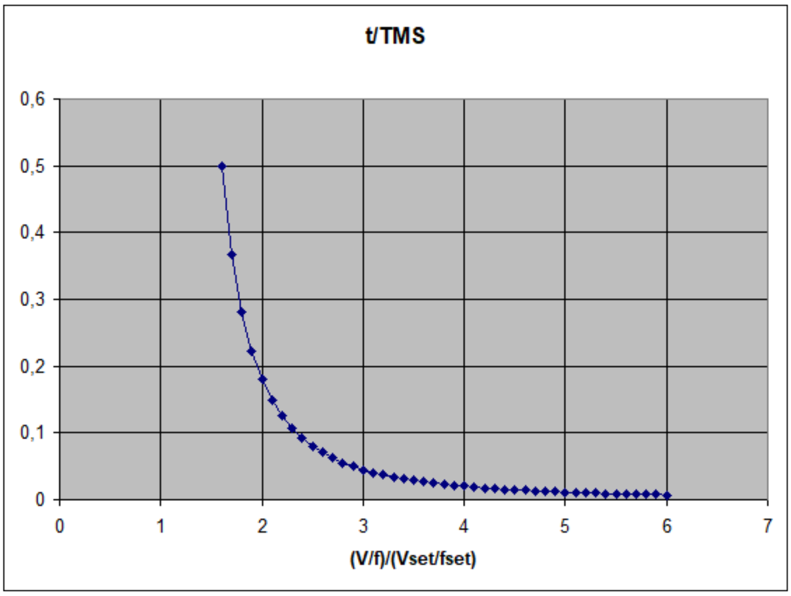
U_{set}/f_{set} = flux setting value.

Figure. 6.3.16 - 78. IEEE standard dependent time characteristics.



The maximum delay time is limited by the parameter VPH24_MaxDel_TPar_ (Max.Time Delay). This time delay is valid if the flux is above the preset value VPH24_EmaxCont_IPar_ (Start U/f LowSet).

Figure. 6.3.16 - 79. IEEE standard dependent time characteristics (enlarged).



This inverse type characteristic is also combined with a minimum time delay, the value of which is set by user parameter VPH24_MinDel_TPar_ (Min. Time Delay). This time delay is valid if the flux is above the setting value VPH24_Emax_IPar_ (Start U/f HighSet).

Reset time

If the calculated flux is below the drop-off flux value (when *s*G < 0.95*G), then thecalculated flux value decreases linearly to zero. The time to reach zero is defined by the parameter VPH24_CoolDel_TPar_ (Cooling Time).

Analogue input of the function

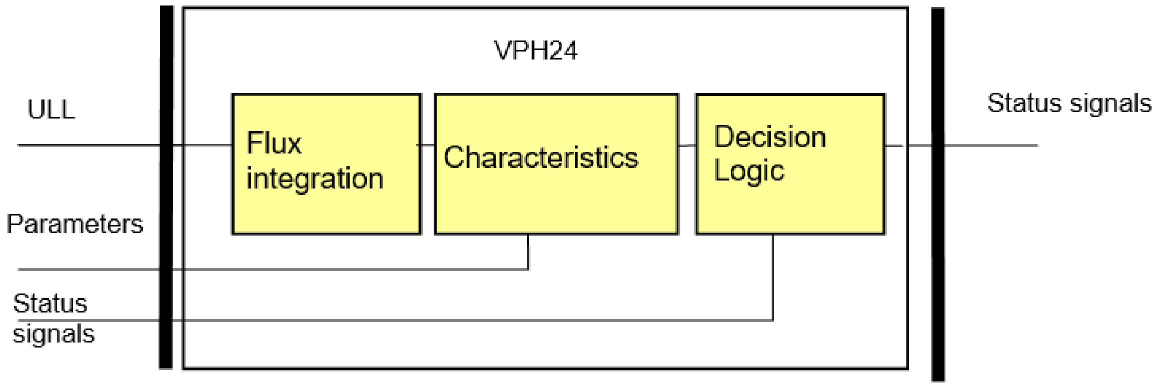
Overexcitation is a typically symmetrical phenomenon. There are other dedicated protection functions against asymmetry. Accordingly, the processing of a single voltage is sufficient. In a network with isolated neutral, the phase voltage is not exactly defined due to the uncertain zero sequence voltage component. Therefore, line-to-line voltages are calculated based on the measured phase voltages, and one of them is assigned to overfluxing protection.

As overexcitation is a phenomenon which is typical if the generator or the generator transformer unit is not connected to the network, the voltage drop does not need any compensation. If the voltage is measured at the supply side of the unit transformer, then the voltage is higher then the voltage of the magnetization branch of the transformer's equivalent circuit. Thus the calculated flux cannot be less then the real flux value. The protection operates with increased security.

Structure of the overexcitation protection function

Figure below shows the structure of the overexcitation protection (VPH24) algorithm.

Figure. 6.3.16 - 80. Structure of the overexcitation protection function.



The inputs are

- The sampled values of a line-to-line voltage (ULL)
- Parameters
- Status signals.

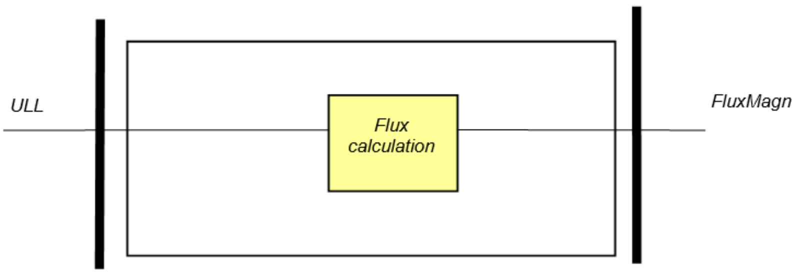
The outputs are

- The binary output status signals.

The software modules of the overexcitation protection function:

- Flux saturation
  This module integrates the voltage to obtain the flux time-function and determines the magnitude of the flux. The inputs are the sampled values of a line-to-line voltage (ULL). The output is the magnitude of the flux (FluxMagn), internal signal.

Figure. 6.3.16 - 81. Principal scheme of the flux calculation.



- Characteristics
  This module calculates the required time delay based on the magnitude of the flux and the parameter settings.
- Decision logic
  The decision logic module combines the status signals to generate the trip command of the function.

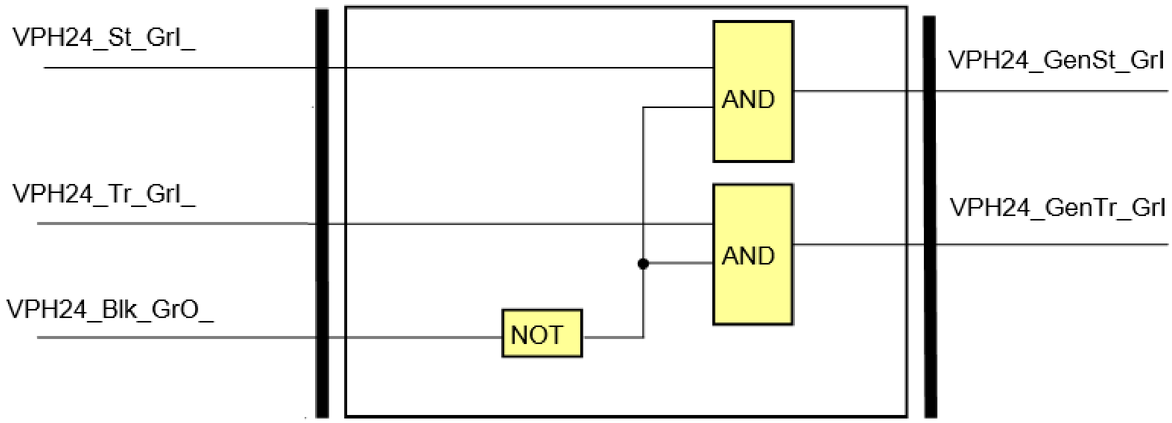


Table. 6.3.16 - 42. Binary status signals.

Binary output signals	Signal title	Explanation
VPH24_GenSt_GrI_	General Start	General starting of the function
VPH24_GenTr_GrI_	General Trip	General trip command of the function
Binary status signal	**Explanation**	
VPH24_Blk_GrO_	Output status defined by the user to disable the overexcitation protection function.	
VPH24_St_GrI_	Starting of the function	
VPH24_Tr_GrI_	Trip command of the function	

Figure. 6.3.16 - 82. The function block of the overexcitation protection function.

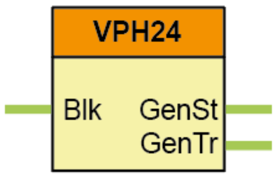


Table. 6.3.16 - 43. Setting parameters of the overexcitation protection function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off Definite time IEEE	-	Definite time	Operating mode selection for the function. Operation can be either disabled “Off” or definite time or IEEE inverse characteristics.
Start U/f	80…140 %	1 %	110 %	Pick-up setting of the function
Time multiplier	1…100	1	10	Time multiplier for inverse time characteristics

Parameter	Setting value / range	Step	Default	Description
Min Time Delay	0.5…60 s	0.01 s	10 s	Minimum time delay for inverse time characteristics or delay for the definite time characteristics.
Max Time Delay	300…8 000 s	0.01 s	3 000 s	Maximum time delay for inverse time characteristics.
Cooling time	60…8 000 s	0.01 s	1 000 s	Reset time delay for inverse time characteristics.

6.3.17 Inrush current detection (68)

The current can be high during transformer energizing due to the current distortion caused by the transformer iron core asymmetrical saturation. In this case, the second harmonic content of the current is applied to disable the operation of the desired protection function(s).

The inrush current detection function block analyses the second harmonic content of the current, related to the fundamental harmonic. If the content is high, then the assigned status signal is set to "true" value. If the duration of the active status is at least 25 ms, then the resetting of the status signal is delayed by an additional 15 ms. Inrush current detection is applied to residual current measurement also with dedicated separate function.

Table. 6.3.17 - 44. Setting parameters of the inrush current function.

Parameter	Setting value / range	Step	Default	Description
Operation	Off Current Contact Current/ Contact	-	Current	Operating mode selection for the function. Operation can be either disabled "Off" or monitoring either measured current or contact status or both current and contact status.
Start current Ph	20…200 %	1 %	30 %	Pick-up current for the phase current monitoring.
Start current N	10…200 %	1 %	30 %	Pick-up current for the residual current monitoring.
Backup Time Delay	60…1 000 ms	1 ms	200 ms	Time delay for CBFP tripping command for the back-up breakers from the pick-up of the CBFP function monitoring.
Pulse length	0…60 000 ms	1 ms	100 ms	CBFP pulse length setting.

6.4 Control, monitoring and measurements

6.4.1 Common function

The AQ300 series devices – independently of the configured protection functions – have some common functionality. The Common function block enables certain kind of extension this common functionality:

1. The WARNING signal of the device
The AQ300 series devices have several LED-s on the front panel. The upper left LED indicates the state of the device:

- Green means normal operation
- Yellow means WARNING state
    - The device is booting while the protection functions are operable
    - No time synchron signal is received
    - There are some setting errors such as the rated frequency setting does not correspond to the measured frequency, mismatch in vector group setting in case of transformer with three voltage levels, etc.
    - Wrong phase-voltage v.s. line-to-line voltage assignment
    - No frequency source is assigned for frequency related functions
    - The device is switched off from normal mode to Blocked or Test or Off mode
    - The device is in simulation mode
    - There is some mismatch in setting the rated values of the analog inputs.
- Red means ERROR state. (This state is indicated also by the dedicated binary output of the power supply module.

The list of the sources of the WARNING state can be extended using the Common function block. This additional signal is programmed by the user with the help of the graphic logic editor.

2. The latched LED signals

The latched LED signals can be reset:

- By the dedicated push button below the LED-s on the front panel of the device
- Using the computer connection and generating a LED reset command
- Via SCADA system, if it is configured
    - The list of the sources of the LED reset commands can be extended using the Common function block. This additional signal is programmed by the user with the help of the graphic logic editor.

The list of the sources of the LED reset commands can be extended using the Common function block. This additional signal is programmed by the user with the help of the graphic logic editor.

3. The Local/Remote state for generating command to or via the device

The Local/Remote state of the device can be toggled:

- From the local front-panel touch-screen of the device

The Local/Remote selection can be extended using the Common function block. There is possibility to apply up to 4 groups, the Local/Remote states of which can be set separately. These additional signals are programmed by the user with the help of the graphic logic editor.

4. AckButton output

AckButton output of the common function block generates a signal whenever the “X” button in the front panel of the relay has been pressed.

5. FixFalse/True

FixFalse/True can be used to write continuous 0 or 1 into an input of a function block or a logic gate.

The Common function block has binary input signals. The conditions are defined by the user applying the graphic logic editor.

Figure. 6.4.1 - 83. The function block of the common function block.

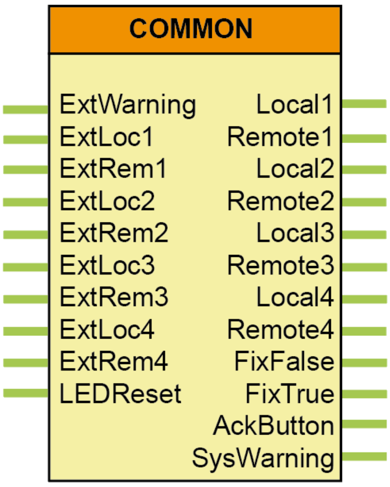


Table. 6.4.1 - 45. The binary output status signals.

Binary output status signal	Title	Explanation
Common_ExtWarning_GrO_	ExtWarning	Input to generate a Warning state of the device.
Common_ExtLoc1_GrO_	ExtLoc1	Input1 to set the state of group 1 to Local
Common_ExtRem1_GrO_	ExtRem1	Input1 to set the state of group 1 to Remote
Common_ExtLoc2_GrO_	ExtLoc2	Input2 to set the state of group 2 to Local
Common_ExtRem2_GrO_	ExtRem2	Input2 to set the state of group 2 to Remote
Common_ExtLoc3_GrO_	ExtLoc3	Input3 to set the state of group 3 to Local
Common_ExtRem3_GrO_	ExtRem3	Input3 to set the state of group 3 to Remote
Common_ExtLoc4_GrO_	ExtLoc4	Input4 to set the state of group 4 to Local
Common_ExtRem4_GrO_	ExtRem4	Input4 to set the state of group 4 to Remote
LEDReset	LED reset	Input to reset the LEDs on the front panel of the device.

Table. 6.4.1 - 46. The binary input status signals.

Binary input status signal	Title	Explanation
Common_Local1_GrI_	Local 1	Output 1 to indicate the state of group 1 as Local
Common_Remote1_GrI_	Remote 1	Output 1 to indicate the state of group 1 as Remote
Common_Local2_GrI_	Local 2	Output 2 to indicate the state of group 2 as Local
Common_Remote2_GrI_	Remote 2	Output 2 to indicate the state of group 2 as Remote
Common_Local3_GrI_	Local 3	Output 3 to indicate the state of group 3 as Local
Common_Remote3_GrI_	Remote 3	Output 3 to indicate the state of group 3 as Remote
Common_Local4_GrI_	Local 4	Output 4 to indicate the state of group 4 as Local

Binary input status signal	Title	Explanation
Common_Remote4_Grl_	Remote 4	Output 4 to indicate the state of group 4 as Remote
Common_FixFalse_Grl_	False	Fix signal FALSE to be applied in the graphic logic editor, if needed
Common_FixTrue_Grl_	True	Fix signal TRUE to be applied in the graphic logic editor, if needed
Common_AckButton_Grl_	AckButton	This is the composed signal which resets the LEDs, for further processing
Common_SysWarning_Grl_	SystemWarning	This is the composed signal with the meaning "WARNING state", for further processing

The Common function block has a single Boolean parameter. The role of this parameter is to enable or disable the external setting of the Local/Remote state.

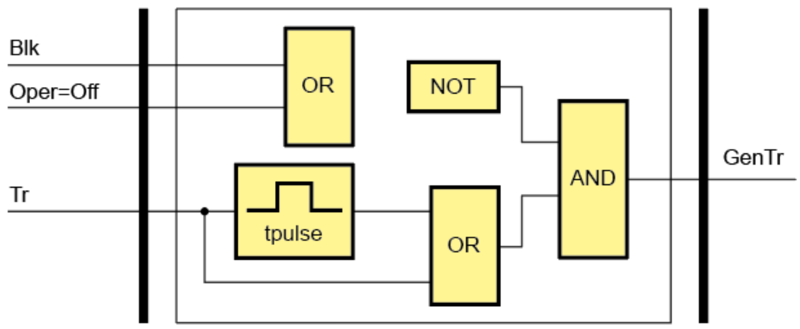
Table. 6.4.1 - 47. Setting parameters.

Parameter	Setting value/ range	Description
Ext LR Source	0	"0" means no external local/remote setting is enabled, the local LCD touch-screen is the only source of toggling.

6.4.2 Trip logic (94)

The simple trip logic function operates according to the functionality required by the IEC 61850 standard for the “Trip logic logical node”. This simplified software module can be applied if only three-phase trip commands are required, that is, phase selectivity is not applied. The function receives the trip requirements of the protective functions implemented in the device and combines the binary signals and parameters to the outputs of the device.

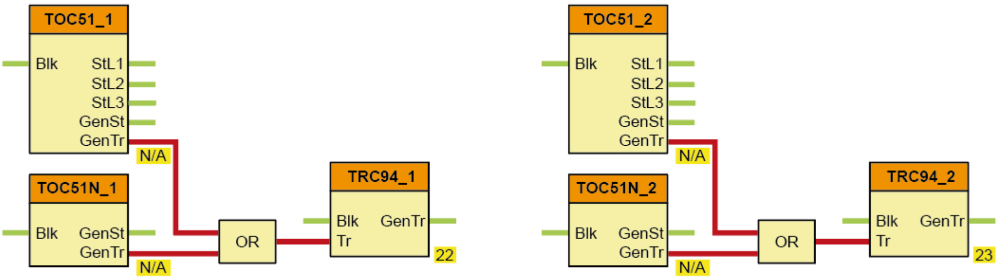
Figure. 6.4.2 - 84. Operation logic of the trip logic function.



The trip requirements can be programmed by the user. The aim of the decision logic is todefine a minimal impulse duration even if the protection functions detect a very short-timefault.

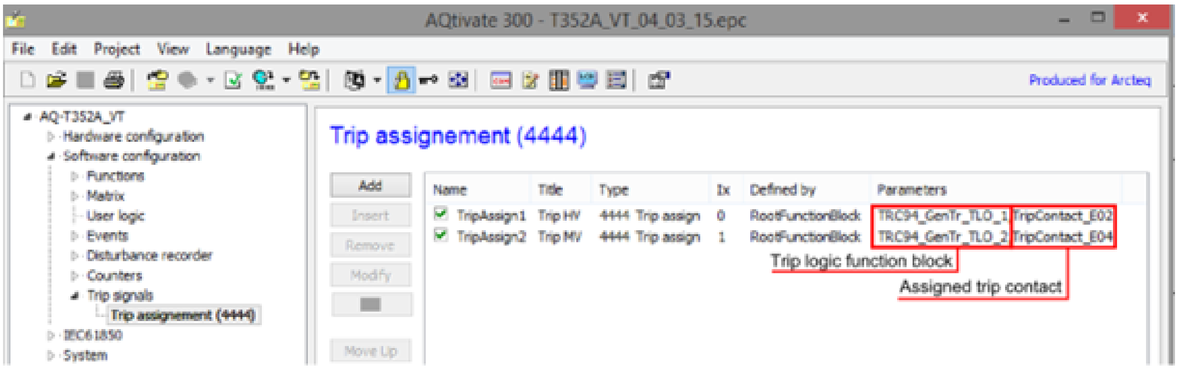
Application example

Figure. 6.4.2 - 85. Example picture where two I> TOC51 and I0> TOC51N trip signals are connected to two trip logic function blocks.



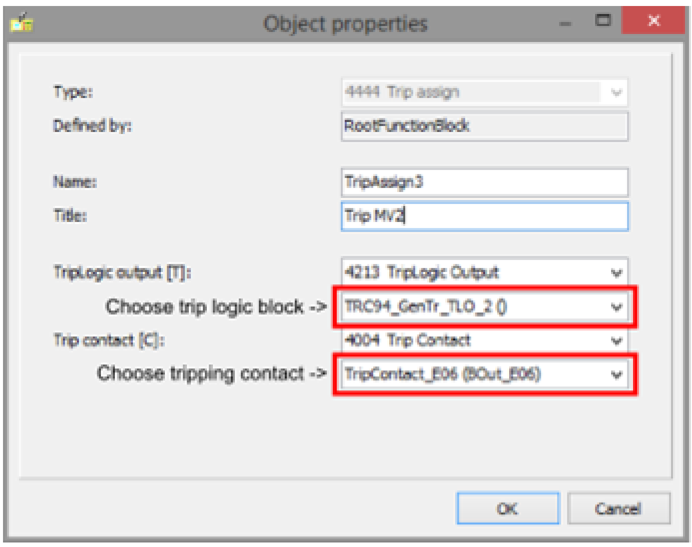
In this example we have a transformer protection supervising phase and residual currentson both sides of the transformer. So in this case the protection function trips have been connected to their individual trip logic blocks (for high voltage side and low voltage side). After connecting the trip signals into trip logic block the activation of trip contacts have to be assigned. The trip assignment is done in Software configuration → Trip signals → Trip assignment.

Figure. 6.4.2 - 86. Trip logic block #1 has been assigned as HV side trip to activate trip contact E02. Trip logic block #2 has been assigned as MV side trip to activate trip contact E04.



The trip contact assignments can be modified or the same trip logic can activate multiple contacts by adding a new trip assignment.

Figure. 6.4.2 - 87. Instructions on adding/modifying trip assignment.



Trip contact connections for wirings can be found in Hardware configuration under Rack designer → Preview or in Connection allocations.

During the parameter setting phase it should be taken care that the trip logic blocks are activated. The parameters are described in the following table.

Setting parameters

Table. 6.4.2 - 48. Setting parameters of the trip logic function.

Parameter	Setting value/range	Step	Default	Description
Operation	On Off	-	On	Operating mode selection for the function. Operation can be either disabled "Off" or enabled "On".
Min pulse length	50…60 000 ms	1 ms	150 ms	Minimum duration of the generated tripping impulse.

6.4.3 Voltage transformer supervision (VTS)

The voltage transformer supervision function generates a signal to indicate an error in the voltage transformer secondary circuit. This signal can serve, for example, a warning, indicating disturbances in the measurement, or it can disable the operation of the distance protection function if appropriate measured voltage signals are not available for a distance decision.

The voltage transformer supervision function is designed to detect faulty asymmetrical states of the voltage transformer circuit caused, for example, by a broken conductor in the secondary circuit. The voltage transformer supervision function can be used for either tripping or alarming purposes.

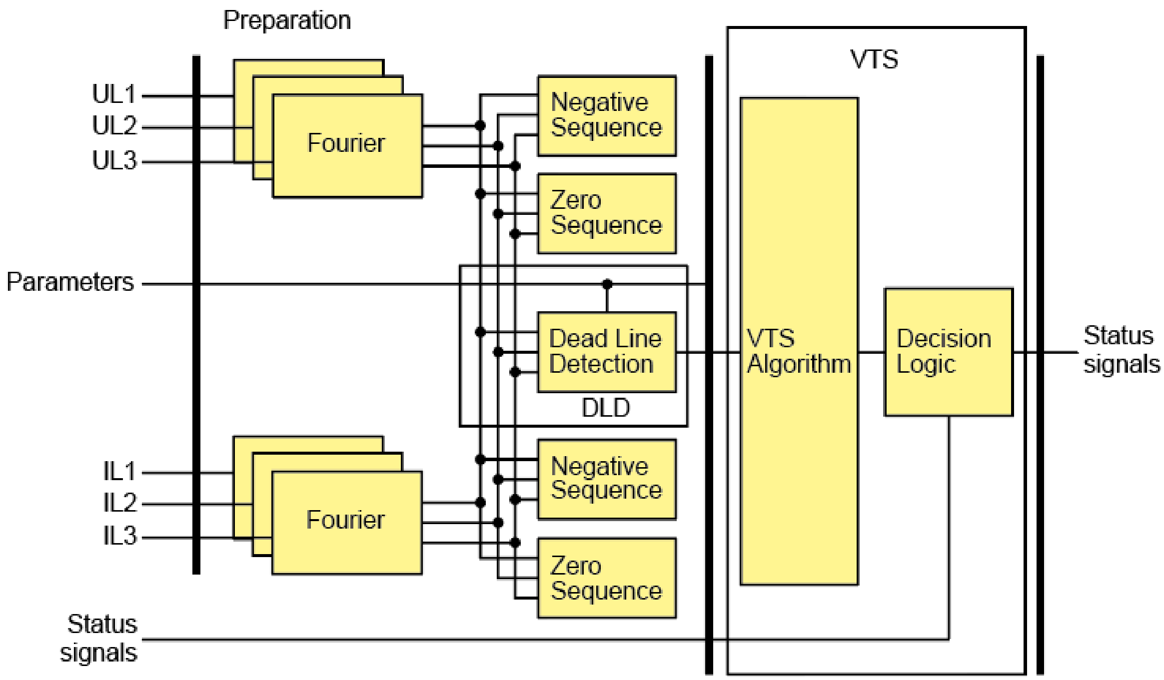
The voltage transformer supervision function can be used in three different modes of application:

- Zero sequence detection (for typical applications in systems with grounded neutral): “VT failure” signal is generated if the residual voltage (3Uo) is above the preset voltage value AND the residual current (3Io) is below the preset current value.
- Negative sequence detection (for typical applications in systems with isolated or resonant grounded (Petersen) neutral): “VT failure” signal is generated if the negative sequence voltage component (U2) is above the preset voltage value AND the negative sequence current component (I2) is below the preset current value.
- Special application: “VT failure” signal is generated if the residual voltage (3Uo) is above the preset voltage value AND the residual current (3Io) AND the negative sequence current component (I2) are below the preset current values.

The voltage transformer supervision function can be triggered if “Live line” status is detected for at least 200 ms. The purpose of this delay is to avoid mal-operation at line energizing if the poles of the circuit breaker make contact with a time delay. The function is set to be inactive if “Dead line” status is detected. If the conditions specified by the selected mode of operation are fulfilled then the voltage transformer supervision function is triggered and the operation signal is generated. When the conditions for operation are no longer fulfilled, the resetting of the function depends on the mode of operation of the primary circuit:

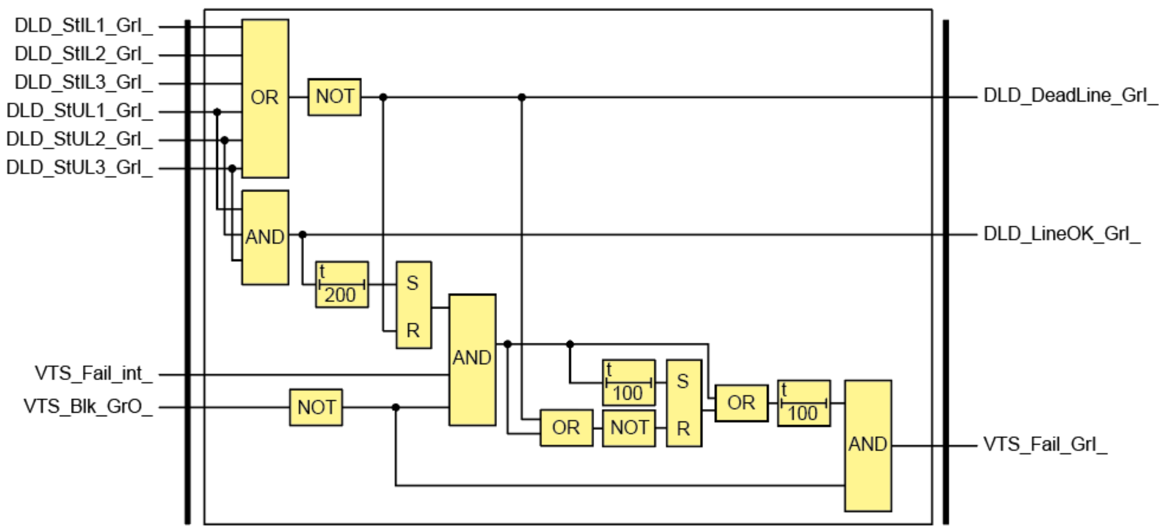
- If the “Live line” state is valid, then the function resets after approx. 200 ms of time delay.
- If the “Dead line” state is started and the “VTS Failure” signal has been continuous for at least 100 ms, then the “VTS failure” signal does not reset; it is generated continuously even when the line is in a disconnected state. Thus, the “VTS Failure” signal remains active at reclosing.
- If the “Dead line” state is started and the “VTS Failure” signal has not been continuous for at least 100 ms, then the “VTS failure” signal resets.

Figure. 6.4.3 - 88. Operation logic of the voltage transformer supervision and dead line detection.



The voltage transformer supervision logic operates through decision logic presented in the following figure.

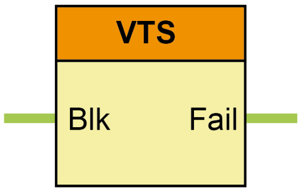
Figure. 6.4.3 - 89. Decision logic of the voltage transformer supervision function.



NOTICE!
For the operation of the voltage transformer supervision function the " Dead line detection function" must be operable as well: it must be enabled by binary parameter.

The function block of voltage transformer supervision function is shown in figure below. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

Figure. 6.4.3 - 90. The function block of the voltage transformer supervision function.



The binary input and output status signals of voltage transformer supervision function are listed in tables below.

Table. 6.4.3 - 49. The binary input and output signals of the VTS function.

Binary status signal	Title	Explanation
VTS_Blk_GrO_	-	Output status defined by the user to disable the voltage transformer supervision function
VTS_Fail_GrI_	VT Failure	Failure status signal of the VTS function

Table. 6.4.3 - 50. Setting parameters of the VTS function.

Parameter	Setting value/ range	Step	Default	Description
Operation	Off Neg. Sequence Zero sequence Special	-	Neg. Sequence	Operating mode selection for the function. Operation can be either disabled "Off" or enabled with criteria "Neg. Sequence", "Zero sequence" or "Special".
Start URes	5…50 %	1 %	30 %	Residual voltage setting limit.
Start IRes	10…50 %	1 %	10 %	Residual current setting limit.
Start UNeg	5…50 %	1 %	10 %	Negative sequence voltage setting limit.
Start INeg	10…50 %	1 %	10 %	Negative sequence current setting limit.

6.4.4 Current transformer supervision (CTS)

The current transformer supervision function can be applied to detect unexpected asymmetry in current measurement.

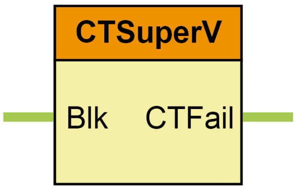
The function block selects maximum and minimum phase currents (fundamental Fourier components). If the difference between them is above the setting limit, the function generates a start signal. For function to be operational the highest measured phase current shall be above 10 % of the rated current and below 150% of the rated current.

The function can be disabled by parameter setting, and by an input signal programmed by the user.

The failure signal is generated after the defined time delay.

The function block of the current transformer supervision function is shown in figure bellow. This block shows all binary input and output status signals that are applicable in the AQtivate300 software.

Figure. 6.4.4 - 91. The function block of the current transformer supervision function.



The binary input and output status signals of the dead line detection function are listed intables below.

Table. 6.4.4 - 51. The binary input and output status signals.

Binary status signal	Title	Explanation
CTSuperV_Blk_GrO_	Block	Blocking of the function
CTSuperV_CtFail_GrI_	CtFail	CT failure signal

Table. 6.4.4 - 52. Setting parameters.

Parameter	Setting value/range	Step	Default	Description
Operation	On Off	-	On	Operating mode selection for the function. Operation can be either disabled "Off" or enabled "On".
IPhase Diff	50…90 %	1 %	80 %	Phase current difference setting.
Time delay	100…60 000 ms	1 ms	1 000 ms	CT supervision time delay.

6.4.5 Synchrocheck (dV/da/df; 25)

Several problems can occur in the power system if the circuit breaker closes and connects two systems operating asynchronously. The high current surge can cause damage in the interconnecting elements, the accelerating forces can overstress the shafts of rotating machines or the actions taken by the protective system can result in the eventual isolation of parts of the power system.

To prevent such problems, this function checks if the systems to be interconnected are operating synchronously. If yes, then the close command is transmitted to the circuit breaker. In case of asynchronous operation, the close command is delayed to wait for the appropriate vector position of the voltage vectors on both sides of the circuit breaker. If the conditions for safe closing cannot be fulfilled within an expected time, then closing is declined.

NOTICE!
For capacitive reference voltage measurement, the voltage measurement card can be ordered with <50 mVA burden special input.

The conditions for safe closing are as follows:

- The difference of the voltage magnitudes is below the set limit.
- The difference of the frequencies is below the set limit.
- The angle difference between the voltages on both sides of the circuit breaker is within the set limit.

The function processes both automatic reclosing and manual close commands.

The limits for automatic reclosing and manual close commands can be set independently of each other.

The function compares the voltage of the line and the voltage of one of the busbar sections (Bus1 or Bus2). The bus selection is made automatically based on a binary input signal defined by the user.

For the reference of the synchrocheck any phase-to-ground or phase-to-phase voltage can be selected.

The function processes the signals of the voltage transformer supervision function and enables the close command only in case of plausible voltages.

The synchrocheck function monitors three modes of conditions:

- Energizing check:
    - Dead bus, live line
    - Live bus, dead line
    - Any Energizing case (including Dead bus, dead line)
- Synchro check (Live line, live bus)
- Synchro switch (Live line, live bus)

If the conditions for “Energizing check” and “Synchro check” are fulfilled, then the function generates the release command, and in case of a manual or automatic close request, the close command is generated.

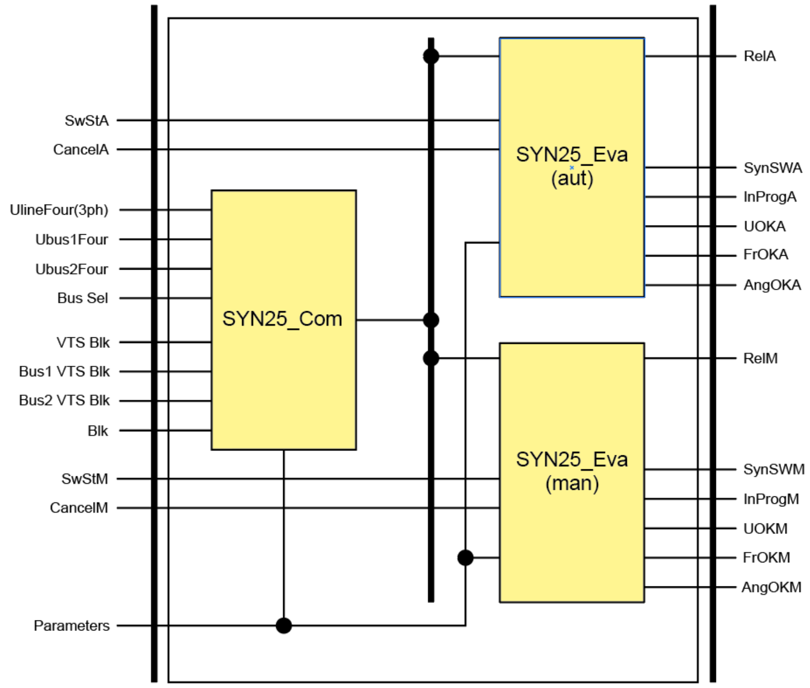
If the conditions for energizing and synchronous operation are not met when the close request is received, then synchronous switching is attempted within the set time-out. In this case, the rotating vectors must fulfill the conditions for safe switching within the set waiting time: at the moment the contacts of the circuit breaker are closed, the voltage vectors must match each other with appropriate accuracy. For this mode of operation, the expected operating time of the circuit breaker must be set as a parameter value, to generate the close command in advance taking the relative vector rotation into consideration.

Started closing procedure can be interrupted by a cancel command defined by the user.

In “bypass” operation mode, the function generates the release signals and simply transmits the close command.

In the following figure is presented the operating logic of the synchrocheck function.

Figure. 6.4.5 - 92. Operation logic of the synchrocheck function.



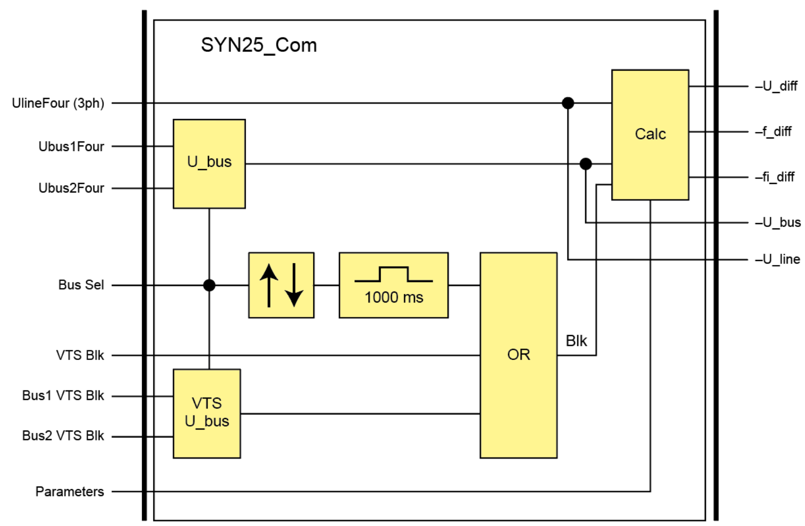
The synchro check/synchro switch function contains two kinds of software blocks:

- SYN25_Com = a common block for manual switching and automatic switching.
- SYN25_EVA = an evaluation block, duplicated for manual switching and for automatic switching.

The SYN25_Com block selects the appropriate voltages for processing and calculates the voltage difference, the frequency difference and the phase angle difference between the selected voltages. The magnitude of the selected voltages is passed for further evaluation.

These values are further processed by the evaluation software blocks. The function is disabled if the binary input (Block) signal is TRUE. The activation of voltage transformer supervision function of the line voltage blocks the operation (VTS Block). The activation of voltage transformer supervision function of the selected bus section blocks the operation (VTS Bus1 Block or VTS Bus2 Block).

Figure. 6.4.5 - 93. Synchrocheck common difference calculation function structure.

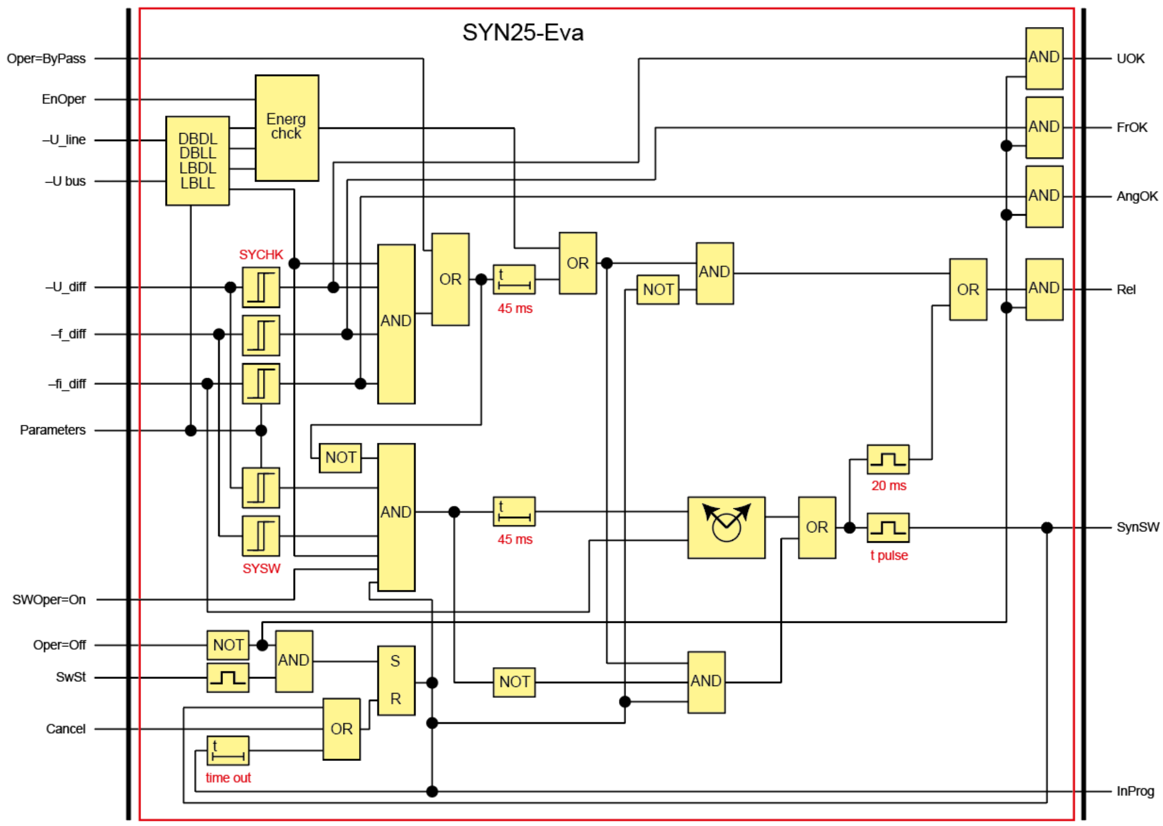


If the active bus section changes the function is dynamically blocked for 1000ms and no release signal or switching command is generated. The processed line voltage is selected based on the preset parameter (Voltage select). The choice is: L1-N, L2-N, L3-N, L1-L2,L2-L3 or L3-L1. The parameter value must match the input voltages received from the bus sections. The active bus section is selected by the input signal (Bus select). If this signal is logic TRUE, then the voltage of Bus2 is selected for evaluation.

The software block SYN25_Eva is applied separately for automatic and manual commands. This separation allows the application to use different parameter values for the two modes of operation.

The structure of the evaluation software block is shown in the following figure.

Figure. 6.4.5 - 94. Synchrocheck evaluation function structure.



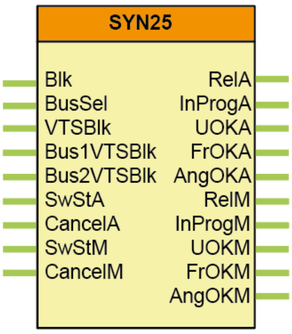
This evaluation software block is used for two purposes: for the automatic reclosing command (the signal names have the suffix "A") and for the manual close request (the signal names have the suffix "M"). As the first step, based on the selected line voltage and bus voltage, the state of the required switching is decided (Dead bus-Dead line, Dead bus-Live line, Live bus-Dead line or Live bus- Live line). The parameters for decision are (U Live) and (U Dead). The parameters (Energizing Auto/Manual) enable the operation individually. The choice is: (Off, DeadBus LiveLine, LiveBus DeadLine, Any energ case). In simple energizing modes, no further checking is needed. This mode selection is bypassed if the parameter (Operation Auto/Manual) is set to "ByPass". In this case the command is transmitted without any further checking.

First, the function tries switching with synchro check. This is possible if: the voltage difference is within the defined limits (Udiff SynChk Auto/Manual)) the frequency difference is within the defined limits (FrDiff SynChk Auto) and the phase angle difference is within the defined limits (MaxPhaseDiff Auto/ Manual)).

If the conditions are fulfilled for at least 45 ms, then the function generates a release output signal (Release Auto/Manual).If the conditions for synchro check operation are not fulfilled and a close request is received as the input signal (SySwitch Auto/Manual), then synchro switching is attempted. This is possible if: the voltage difference is within the defined limits (Udiff SynSW Auto /Manual)) the frequency difference is within the defined limits (FrDiff SynSW Auto).

These parameters are independent of those for the synchro check function. If the conditions for synchro check are not fulfilled and the conditions for synchro switch are OK, then the relative rotation of the voltage vectors is monitored. The command is generated before the synchronous position, taking the breaker closing time into consideration (Breaker Time).The pulse duration is defined by the parameter (Close Pulse). In case of slow rotation and if the vectors are for long time near-opposite vector positions, no switching is possible, therefore the waiting time is limited by the preset parameter (Max.Switch Time).

Figure. 6.4.5 - 95. The function block of the synchrocheck/synchroswitch function.



The progress is indicated by the output status signal (SynInProgr Auto/Manual). The started command can be canceled using the input signal (Cancel Auto/Manual).

The binary input and output status signals of the dead line detection function are listed in tables below.

Table. 6.4.5 - 53. The binary input signals.

Binary status signal	Title	Explanation
SYN25_BusSel_GrO_	Bus Select	If this signal is logic TRUE, then the voltage of Bus2 is selected for evaluation.
SYN25_VTSBlk_GrO_	VTS Block	Blocking signal of the voltage transformer supervision function evaluating the line voltage.
SYN25_Bus1VTSBlk_GrO_	VTS Bus1 Block	Blocking signal of the voltage transformer supervision function evaluating the Bus1 voltage.
SYN25_Bus2VTSBlk_GrO_	VTS Bus2 Block	Blocking signal of the voltage transformer supervision function evaluating the Bus2 voltage.
SYN25_SwStA_GrO_	SySwitch Auto	Switching request signal initiated by the automatic reclosing function.
SYN25_CancelA_GrO_	Cancel Auto	Signal to interrupt (cancel) the automatic switching procedure.
SYN25_Blk_GrO_	Block	Blocking signal of the function.
SYN25_SwStM_GrO_	SySwitch Manual	Switching request signal initiated by manual closing.

Binary status signal	Title	Explanation
SYN25_CancelM_GrO_	Cancel Manual	Signal to interrupt (cancel) the manual switching procedure.

Table. 6.4.5 - 54. The binary output signals.

Binary status signal	Title	Explanation
SYN25_RelA_GrI_	Release Auto	Releasing the close command initiated by the automatic reclosing function.
SYN25_InProgA_GrI_	SynInProgr Auto	Switching procedure is in progress, initiated by the automatic reclosing function.
SYN25_UOKA_GrI_	Udiff OK Auto	The voltage difference is appropriate for automatic closing command.
SYN25_FrOKA_GrI_	FreqDiff OK Auto	The frequency difference is appropriate for automatic closing command, evaluated for synchrocheck.
SYN25_AngOKA_GrI_	Angle OK Auto	The angle difference is appropriate for automatic closing request.
SYN25_RelM_GrI_	Release Man	Releasing the close command initiated by manual closing request.
SYN25_InProgM_GrI_	SynInProgr Man	Switching procedure is in progress, initiated by the manual closing command.
SYN25_UOKM_GrI_	Udiff OK Man	The voltage difference is appropriate for automatic closing command.
SYN25_FrOKM_GrI_	FreqDiff OK Man	The frequency difference is appropriate for manual closing command, evaluated for synchrocheck.
SYN25_AngOKM_GrI_	Angle OK Man	The angle difference is appropriate for manual closing command.

Table. 6.4.5 - 55. Setting parameters.

Parameter	Setting value/ range	Step	Default	Description
Voltage select	L1-N L2-N L3-N L1-L2 L2-L3 L3-L1	-	L1-N	Reference voltage selection. The function will monitor the selected voltage for magnitude, frequency and angle differences.
U Live	60…110 %	1 %	70 %	Voltage setting limit for "Live Line" detection. When measured voltage is above the setting value the line is considered "Live".
U Dead	10…60 %	1 %	30 %	Voltage setting limit for "Dead line" detection. When measured voltage is below the setting value the line is considered "Dead".

Parameter	Setting value/ range	Step	Default	Description
Breaker Time	0…500 ms	1 ms	80 ms	Breaker operating time at closing. This parameter is used for the synchroswitch closing command compensation and it describes the breaker travel time from open position to closed position from the close command.
Close Pulse	10…60 000 ms	1 ms	1 000 ms	Close command pulse length. This setting defines the duration of close command from the IED to the circuit breaker.
Max Switch Time	100…60 000 ms	1 ms	2 000 ms	Maximum allowed switching time. In case synchrocheck conditions are not fulfilled and the rotation of the networks is slow this parameter defines the maximum waiting time after which the close command is failed.
Operation Auto	On Off ByPass	-	On	Operation mode for automatic switching. Selection can be automatic switching off, on or bypassed. If the Operation Auto is set to "Off" automatic switch checking is disabled. If selection is "ByPass" Automatic switching is enabled with bypassing the bus and line energization status checking. When the selection is "On" also the energization status of bus and line are checked before processing the command.
SynSW Auto	On Off	-	On	Automatic synchroswitching selection. Selection may be enabled "On" or disabled "Off".
Energizing Auto	Off DeadBus LiveLine LiveBus DeadLine Any energ case	-	DeadBus LiveLine	Energizing mode of automatic synchroswitching. Selections consist of the monitoring of the energization status of the bus and line. If the operation is wanted to be LiveBus LiveLine or DeadBus DeadLine, the selection is "Any energ case".
Udiff SynChk Auto	5…30 %	1 %	10 %	Voltage difference checking of the automatic synchrocheck mode. If the measured voltage difference is below this setting the condition applies.
Udiff SynSW Auto	5…30 %	1 %	10 %	Voltage difference checking of the automatic synchroswitch mode. If the measured voltage difference is below this setting the condition applies.
MaxPhasediff Auto	5…80 deg	1 deg	20 deg	Phase difference checking of the automatic synchroswitch mode. If the measured phase difference is below this setting the condition applies.
FrDiff SynChk Auto	0.02…0.50 Hz	0.01 Hz	0.02 Hz	Frequency difference checking of the automatic synchrocheck mode. If the measured phase difference is below this setting the condition applies.
FrDiff SynSW Auto	0.10…1.00 Hz	0.01 Hz	0.2 Hz	Frequency difference checking of the automatic synchroswitch mode. If the measured phase difference is below this setting the condition applies.
Operation Man	On Off ByPass	-	On	Operation mode for manual switching. Selection can be manual switching off, on or bypassed. If the Operation Man is set to "Off" manual switch checking is disabled. If selection is "ByPass" manual switching is enabled with bypassing the bus and line energization status checking. When the selection is "On" also the energization status of bus and line are checked before processing the command.

Parameter	Setting value/ range	Step	Default	Description
SynSW Man	On Off	-	On	Manual synchroswitching selection. Selection may be enabled "On" or disabled "Off".
Energizing Man	Off Deadbus LiveLine LiveBus DeadLine Any energ case	-	DeadBus LiveLine	Energizing mode of manual synchroswitching. Selections consist of the monitoring of the energization status of the bus and line. If the operation is wanted to be LiveBus LiveLine or DeadBus DeadLine the selection is "Any energ case".
Udiff SynChk Man	5…30 %	1 %	10 %	Voltage difference checking of the manual synchrocheck mode. If the measured voltage difference is below this setting the condition applies.
Udiff SynSW Man	5…30 %	1 %	10 %	Voltage difference checking of the manual synchroswitch mode. If the measured voltage difference is below this setting the condition applies.
MaxPhaseDiff Man	5…80 deg	1 deg	20 deg	Phase difference checking of the manual synchroswitch mode. If the measured phase difference is below this setting the condition applies.
FrDiff SynChk Man	0.02…0.50 Hz	0.01 Hz	0.02 Hz	Frequency difference checking of the manual synchroswitch mode. If the measured phase difference is below this setting the condition applies.
FrDiff SynSW Man	0.10…1.00 Hz	0.01 Hz	0.2 Hz	Frequency difference checking of the manual synchroswitch mode. If the measured phase difference is below this setting the condition applies.

6.4.6 Integrated automatic voltage regulator (AVR)

One of the most important criteria for power quality is to keep the voltage of selected points of the network within the prescribed limits. The most common mode of voltage regulation is the application of transformers with on-load tap changers. When the transformer is connected to different taps, its turns ratio changes and supposing constant primary voltage, the secondary voltage can be increased or decreased as required.

Voltage control can take the actual load state of the transformer and the network into consideration. As a result, the voltage of a defined remote point of the network is controlled assuring that neither consumers near the busbar nor consumers at the far ends of the network get voltages out of the required range.

The voltage control function can be performed automatically or, in manual mode of operation, the personnel of the substation can set the network voltage according to special requirements.

Depending on the selected mode of operation this version of the controller can be applied to regulate a single transformer or to control parallel transformers.

When transformers are connected parallel, i.e. they are connected to the same busbar section on the primary side and also on the secondary side of the transformer, then these transformers must be regulated together to avoid circulating current among the transformers.

This circulating current causes additional losses, and the generated additional heat could overstress the transformers.

The “Operation” parameter for selection of the operating mode has several choices:

- Off, for disabling the control function
- Single, for regulation a single transformer only
- CircCurrMin, for operating the controllers of the parallel connected transformers to minimize the circulating current
- Master, for selection one of the controllers of the parallel connected transformers to be the master, to transmit commands to the slave controllers
- SlaveCmd, for selection the controller to operate in slave mode, and follow the UP and DOWN commands
- SlaveTap for selection the controller to operate in slave mode, and drive the tap changer to the same position as the transformer assigned to the master controller.

In any of the active modes of operation the controllers can be set to the “Manual” or to “Automatic” control command generation.

Mode of operation to control a single transformer

This mode of operation is selected if the "Operation" parameter is set to "Single".

The scheme of the function block

Figure below shows the scheme of the function block, simplified for single mode of operation.

Analog inputs of the controller function

The automatic tap changer controller function receives the following analog inputs:

- UL1L2 = line-to-line voltage of the controlled secondary side of the transformer
- IL1L2 = difference of the selected line currents of the secondary side of the transformer for voltage drop compensation
- IHV = maximum of the phase currents of the primary side of the transformer for limitations purposes

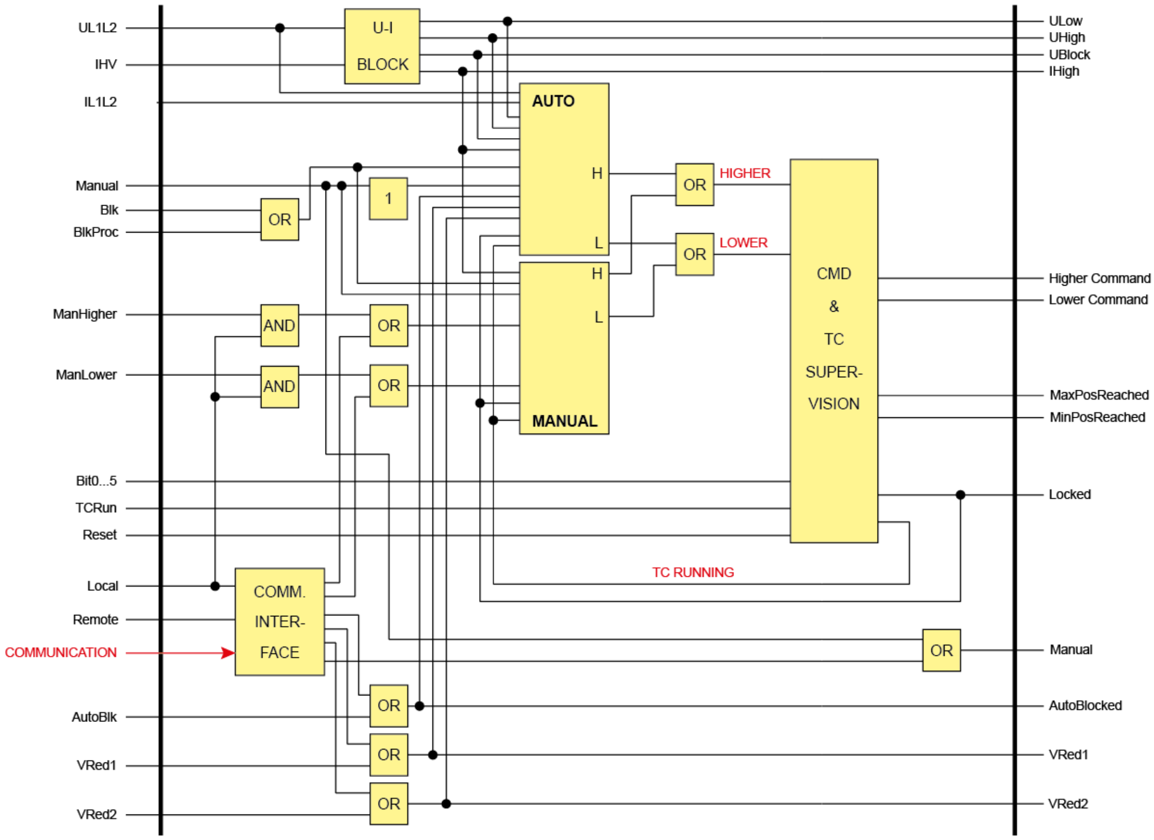
The parameter "U Correction" permits fine tuning of the measured voltage.

Internal checks before control operation

In Figure below the block “U-I BLOCK” performs the following checks before control operation:

- If the voltage of the controlled side UL1L2 is above the value set by the parameter.
- “U High Limit”, then control command to increase the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter.
- “U Low Limit”, then control command to decrease the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter.
- “U Low Block”, then the transformer is considered to be de-energized and the automatic control is completely disabled.
- If the current of the supply side IHV is above the limit set by the parameter “I_overload”, then both automatic and manual controls are completely disabled. This is to protect the switches inside the tap changer.

Figure. 6.4.6 - 96. The logic schema of the automatic tap changer controller



Automatic control mode

Voltage compensation in automatic control mode

The module "AUT" in the figure above ("The logic schema of the automatic tap changer controller") gets the Fourier components of the busbar voltage and those of the current:

- $UL1L2_{Re}$ and $UL1L2_{Im}$
- $IL1L2_{Re}$ and $IL1L2_{Im}$

In automatic control mode the voltage of the controlled side UL1L2 is compensated by the current of the controlled side IL1L2. This means that the voltage of the "load center" of the network is controlled to be constant, in fact within a narrow range. This assures that neither the voltage near to the busbar is too high, nor the voltage at far-away points of the network is too low. The voltage of the "load center", i.e. the controlled voltage is calculated as:

$$|Ucontrol| = |Ubus - Udrop|$$

There are two compensation modes to be selected by setting the "Compensation" parameter: "AbsoluteComp" and "ComplexComp".

- If the parameter "Compensation" is set to "AbsoluteComp", the calculation method is as follows:

In this simplified method the vector positions are not considered correctly, the formula above is approximated with the magnitudes only:

$$|Ucontrol| = |Ubus - Udrop| \approx |Ubus| - |Udrop| \approx |Ubus| - |I| * (R)CompoundFactor$$

, where (R) Compound Factor is a parameter value.

If the "|I|" current is above the value defined by the parameter "I Comp Limit", then in the formulas above this preset value is considered instead of the higher values measured.

The method is based on the experiences of the network operator. Information is needed: how much is the voltage drop between the busbar and the "load center" if the load of the network is the rated load. The parameter "(R) Compound Factor" means in this case the voltage drop in percent.

> NOTICE!
> If the active power flows from the network to be controlled to the busbar then in "AbsoluteComp" mode no compounding is performed.

- If the parameter "Compensation" is set to "ComplexComp", the calculation method is as follows:

In this method the vector positions are partly considered. In the formula above the voltage drop is approximated with the component of the voltage drop, the direction of which is the same as the direction of the bus voltage vector. (This is "length component" of the voltage drop; the "perpendicular component" of the voltage drop is neglected.)

$$|Ucontrol| = \left|Ubus - \left[(IL1L2_{Re} + jIL1L2_{im}) * \left((R)CompoundFactor + jXCompoundFactor\right)\right]\right|$$

, where (R) Compound Factor and X Compound Factor are parameter values.

The voltage of the "load center" of the network is controlled to be within a narrow range. This assures that neither the voltage near to the busbar is too high, nor the voltage at far-away points of the network is too low.

The method is based on the estimated complex impedance between the busbar and the "load center". The parameter "(R) Compound Factor" means in this case the voltage drop in percent, caused by the real component of the rated current.

The parameter "X Compound Factor" means in this case the voltage drop in percent, caused by the imaginary component of the rated current.

<u>Voltage checking in automatic control mode</u>

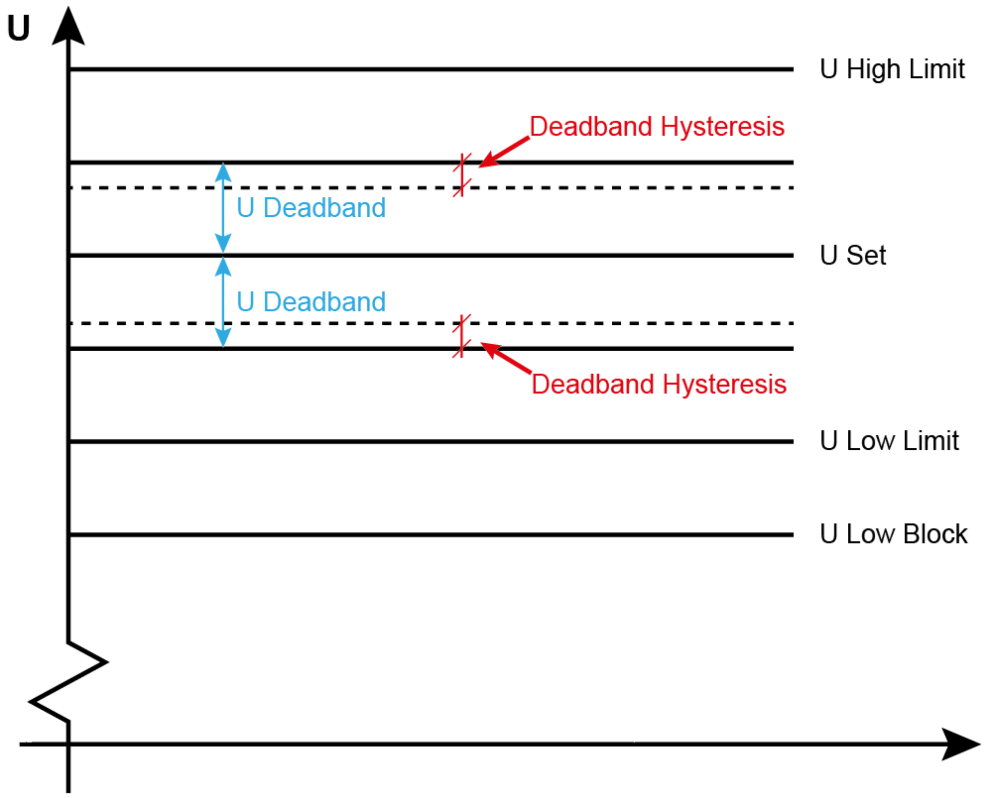
In automatic control mode the calculated | Ucontrol | voltage is checked to see if it is outside the limits. The limits are defined by parameter values:

- U Set = the setting value defininf the centre of the permitted range
- U deadband = the width of the permitted range in both + and – directions
- Deadband Hysteresis = the hysteresis decreasing the permitted range after the generation of the control command

If the calculated | Ucontrol | voltage is outside the limits, then timers are started.

In an emergency state of the network, when the network elements are overloaded, the "Uset" value can be driven to two lower values defined by the parameters "Voltage Reduction 1" and "Voltage Reduction 2". "U Set" is decreased by the parameter values if the binary inputs "Voltage Reduction 1" or "Voltage Reduction 2" enter into active state. These inputs must be programmed graphically by the user.

Figure. 6.4.6 - 97. Voltage level settings.



<u>Time delay in automatic control mode</u>

In automatic control mode the first and every subsequent control command is processed separately.

For the first control command:

The voltage difference is calculated:

$$Udiff = |Ucontrol - Uset|$$

If this difference is above the “U Deadband” value, then depending on the setting of parameter “T1 Delay Type”, three different timing modes can be selected:

- "Definite": this definite time delay is defined by parameter T1

- "Inverse": the standard IDMT characteristic defined by the parameters:
  - T1: the maximum delay defined by the parameter
  - "U Deadband": the width of the permitted range in both + and – directions
  - "Min Delay": minimum time delay

$$Tdelay = \frac{T1}{\left(\frac{Udiff}{Udeadband}\right)}, but\ minimum\ MinDelay$$

  - "2powerN"

$$Tdelay = T1 \times 2\left(1 - \frac{Udiff}{Udeadband}\right)$$

The binary parameters “Fast Lower Enable” and/or “Fast Higher Enable” enable fast command generation if the voltage is above the parameter value “U High Limit” or below the “U Low Limit”. In this case, the time delay is a definite time delay defined by parameter “T2”.

For subsequent control commands:

In this case, the time delay is always a definite time delay defined by parameter “T2” if the subsequent need for regulation with the same direction is detected within the “Reclaim time” defined by parameter.

The automatic control mode can be blocked by a binary signal received via binary input “AutoBlk” and generates a binary output signal “AutoBlocked (ext)”

Manual control mode

In manual mode, the automatic control is blocked. The manual mode can be “Local” or “Remote”. For this mode, the input “Manual” needs to be in active state (as programmed by the user).

In the local mode, the input “Local” needs to be in active state. The binary inputs “ManHigher” or “ManLower” must be programmed graphically by the user.

In the remote mode, the input “Remote” needs to be in active state as programmed by the user. In this case manual commands are received via the communication interface.

Command generation and tap changer supervision

The software module “CMD&TC SUPERV” is responsible for the generation of the “HigherCmd” and “LowerCmd” command pulses, the duration of which is defined by the parameter “Pulse Duration”. This is valid both for manual and automatic operation.

The tap changer supervision function receives the information about the tap changer position in six bits of the binary inputs “Bit0 to Bit5”. The value is decoded according to the enumerated parameter “CodeType”, the values of which can be: Binary, BCD or Gray. During switchover, for the transient time defined by the parameter “Position Filter”, the position is not evaluated.

The parameters “Min Position” and “Max Position” define the upper and lower limits. In the upper position, no further increasing command is generated and the output “Max Pos Reached” becomes active. Similarly, in the lower position, no further decreasing command is generated and the output “Min Pos Reached” becomes active.

The function also supervises the operation of the tap changer. Depending on the setting of parameter “TC Supervision”, three different modes can be selected:

- TCDrive the supervision is based on the input "TCRun". In this case, after command generation the drive is expected to start operation within one quarter of the value defined by the parameter "Max Operating Time" and it is expected to perform the command within "Max Operating Time".
- Position the supervision is based on the tap changer position in six bits of the binary inputs "Bit0 to Bit5". It is checked if the tap position is incremented in case of a voltage increase, or the tap position is decremented in case of a voltage decrease, within the "Max Operating Time".
- Both in this mode the previous two modes are combined.

In case of an error detected in the operation of the tap changer, the "Locked" input becomes active and no further commands are performed. To enable further operation, the input "Reset" must be programmed for an active state by the user.

Error codes

The On-line information includes a variable "ErrorCode" (ATCC_ErrCode_ISt_), indicating different error states. These states are binary coded; any of them causes "Locked" state of the controller function. The explanation of the individual bits in the code value is explained in the table below.

Table. 6.4.6 - 56.

Bit	Value	Explanation
0	1	Drive started without control command
1	2	Drive did not start after control command
2	4	Drive did not stop in due time
3	8	Invalid position signal
4	16	Position signal did not change value

In case of multiple error states the values are added in the "Error Code".

Symbol of the function in AQtivate300 software

Figure. 6.4.6 - 98. Function block of the automatic tap changer controller.

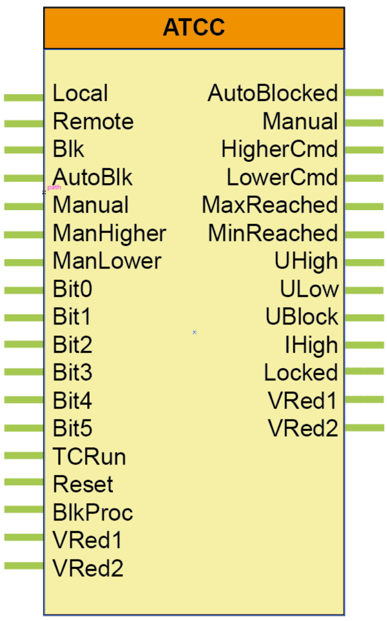


Table. 6.4.6 - 57. Outputs of the ATCC function block.

Title	Explanation
AutoBlocked	Automatic control blocked
Manual	Signaling the manual mode of operation
Higher Command	Command for increasing the voltage
Lower Command	Command for decreasing the voltage
Max Pos Reached	Signaling the maximal position
Min Pos Reached	Signaling the minimal position
U High	Voltage is high
U Low	Voltage is low
U Block	Blocked state for too low voltage
I High	Blocked because of current limits
Locked	The supervision detected tap changer error, the blocking can be released exclusively by the Reset impulse
Voltage reduction 1	Controlling the reduced voltage 1
Voltage reduction 2	Controlling the reduced voltage 2

Table. 6.4.6 - 58. Inputs of the ATCC function block.

Title	Explanation
Local	Local state of the manual operation
Remote	Remote state of the manual operation
Blk	Blocking of the function
AutoBlk	Blocking of the automatic function
Manual	Manual mode of operation
ManHigher	Manual command for increasing the voltage
ManLower	Manual command for decreasing the voltage
Bit0	Bit0 of the position indicator
Bit1	Bit1 of the position indicator
Bit2	Bit2 of the position indicator
Bit3	Bit3 of the position indicator
Bit4	Bit4 of the position indicator
Bit5	Bit5 of the position indicator

Title	Explanation
TCRun	Running state of the tap changer
Reset	Reset to release from blocked state
BlkProc	Blocking signal from the tap changer
VRed1	Reduced voltage 1 is required
VRed2	Reduced voltage 2 is required

Table. 6.4.6 - 59. Setting parameters of the automatic tap changer controller function (enumerated parameters).

Enumerated parameter name	Selection range	Enumerated parameter description
ControlMode	Direct normal Direct enhanced SBO enhanced	Control mode, according to IEC 61850
sboClass	Operate-once Operate many	Selected before operate class, according to IEC 61850
Operation	Off On	Parameter for general blocking of the function
T1 Delay type	Definite Inverse 2powerN	Parameter for time delay mode selection
Compensation	Off AbsoluteComp ComplexComp	Selection for compensation mode
TC Supervision	Off TCDrive Position Both	Tap changed supervision mode selection
Code Type	Binary BCD Gray	Decoding of the position indicator data

Table. 6.4.6 - 60. Setting parameters of the automatic tap changer controller function (Boolean parameters).

Boolean parameter name	Default	Boolean parameter description
Fast Higher Enable	0	Enabling fast higher control command
Fast Lower Enable	0	Enabling fast lower control command

Table. 6.4.6 - 61. Setting parameters of the automatic tap changer controller function (integer parameters).

Integer parameter name	Min	Max	Step	Default	Integer parameter description
Min Position	1	32	1	1	Code value of the minimum position
Max Position	1	32	1	32	Code value of the maximum position

Table. 6.4.6 - 62. Setting parameters of the automatic tap changer controller function (timer parameters).

Timer parameter name	Unit	Min	Max	Step	Default	Timer parameter description
Max operating time	ms	1,000	30,000	1	5,000	Time limit for tap change operation
Pulse duration	ms	100	10,000	1	1,000	Command impulse duration
Position filter	ms	1,000	30,000	1	3,000	Time overbridging the transient state of the tap changer status signals
SBO timeout	ms	1,000	20,000	1	5,000	Select before operate timeout, according to IEC 61850

Table. 6.4.6 - 63. Setting parameters of the automatic tap changer controller function (float parameters).

Float parameter name	Unit	Min	Max	Digits	Default	Float parameter description
U Correction	-	0.950	1.050	3	1.000	Factor for fine-tuning the measured voltage.
U Set	%	80.0	115.0	1	100.0	Set point for voltage regulation, related to the rated voltage (valid at I=0).
U Deadband	%	0.5	9.0	1	3.0	Deadband for voltage regulation, related to the rated voltage.
Deadband hysteresis	%	60	90	0	85	Hysteresis value for the deadband, related to the deadband.
(R) Compound factor	%	0.0	15.0	1	5.0	Parameter for the current compensation.
X Compound factor	%	0.0	15.0	1	5.0	Parameter for the current compensation.
Voltage reduction 1	%	0.0	10.0	1	5.0	Reduced set point 1 for voltage regulation (priority), related to the rated voltage.
Voltage reduction 2	%	0.0	10.0	1	5.0	Reduced set point 2 for voltage regulation, related to the rated voltage.
I Comp Limit	%	0	150	0	1	Maximum current value to be considered in current compensation equations.
I Overload	%	50	150	0	100	Current upper limit to disable all operation.
U High Limit	%	90.0	120.0	1	110.0	Voltage upper limit to disable all operation.
U Low Limit	%	70.0	110.0	1	90.0	Voltage lower limit to disable step down.

Float parameter name	Unit	Min	Max	Digits	Default	Float parameter description
U Low Block	%	50.0	100.0	1	70.0	Voltage lower limit to disable all operation.
T1	s	1.0	600.0	1	10.0	Time delay for the first control command generation.
T2	s	1.0	100.0	1	10.0	Definite time delay for control command generation or fast operation (if it is enabled).
Min Delay	s	1.0	100.0	1	10.0	In case of dependent time characteristics, this is the minimum time delay.
Reclaim Time	s	1.0	100.0	1	10.0	After a control command, if the voltage is out of the range within reclaim time, then the command is generated after T2 time delay.

6.4.7 Switch-on-to-fault

Some protection functions, e.g. distance protection, directional overcurrent protection, etc. need to decide the direction of the fault. This decision is based on the angle between the voltage and the current. In case of close-in faults, however, the voltage of the faulty loop is near zero: it is not sufficient for a directional decision. If there are no healthy phases, then the voltage samples stored in the memory are applied to decide if the fault is forward or reverse.

If the protected object is energized, the close command for the circuit breaker is received in “dead” condition. This means that the voltage samples stored in the memory have zero values. In this case the decision on the trip command is based on the programming of the protection function for the “switch-onto-fault” condition.

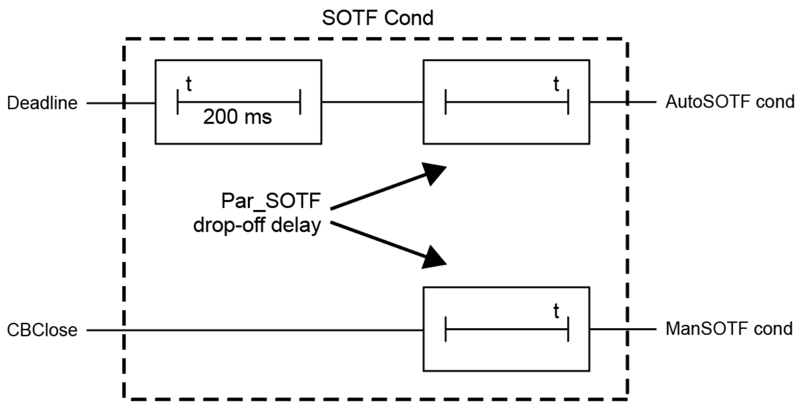
This “switch-onto-fault” (SOTF) detection function prepares the conditions for the subsequent decision. The function can handle both automatic and manual close commands.

The function receives the “Dead line” status signal from the DLD (dead line detection) function block. After dead line detection, the binary output signal AutoSOTF is delayed by a timer with a constant 200 ms time delay. After voltage detection (resetting of the dead line detection input signal), the drop-off of this output signal is delayed by a timer (SOTF Drop Delay) set by the user. The automatic close command is not used it is not an input for this function.

The manual close command is a binary input signal. The drop-off of the binary output signal ManSOTF is delayed by a timer (SOTF Drop Delay) set by the user. The timer parameter is common for both the automatic and manual close command.

The operation of the “switch-onto-fault” detection function is shown in Figure below.

Figure. 6.4.7 - 99. The scheme of the switch-on-to-fault preparation.



The binary input signals of the “switch-onto-fault” detection function are:

- CBClose Manual close command to the circuit breaker.
- DeadLine Dead line condition detected; this is usually the output signal of the DLD (dead line detection) function block.

The binary output signals of the “switch-onto-fault” detection function are:

- AutoSOTF cond Signal enabling switch-onto-fault detection as a consequence of an automatic close command.
- ManSOTF cond Signal enabling switch-onto-fault detection as a consequence of a manual close command.

Figure. 6.4.7 - 100. The function block of the switch-on-to-fault function.

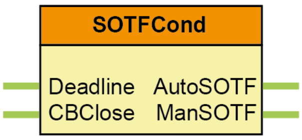


Table. 6.4.7 - 64. The timer parameter of the function.

Parameter	Title	Unit	Min	Max	Step	Default
Drop-off time delay for the output signals.						
SOTF_SOTFDel_TPar_	SOTF Drop Delay	ms	100	10 000	1	1000

Table. 6.4.7 - 65. The binary input and output status signals of the function.

Binary status signal	Signal title	Explanation
SOTF_AutoSOTF_GrI_	AutoSOTF cond	Signal enabling switch-on-to-fault detection as a consequence of automatic close command.
SOTF_Man_SOTF_GrI_	ManSOTF cond	Signal enabling switch-on-to-fault detection as a consequence of manual close command.
SOTF_CBClose_GrO_	CBClose	Manual close command to the circuit breaker.
SOTF_DeadLine_GrO_	DeadLine	Dead line condition detected.

6.4.8 Disturbance recorder

The disturbance recorder function can record analog signals and binary status signals. These signals are user configurable. The disturbance recorder function has a binary input signal, which serves the purpose of starting the function. The conditions of starting are defined by the user. The disturbance recorder function keeps on recording during the active state of this signal but the total recording time is limited by the timer parameter setting. The pre-fault time, max-fault time and post-fault time can be defined by parameters.

If the conditions defined by the user - using the graphic equation editor – are satisfied, then the disturbance recorder starts recording the sampled values of configured analog signals and binary signals. The analog signals can be sampled values (voltages and currents) received via input modules or they can be calculated analog values (such as negative sequence components, etc.) The number of the configured binary signals for recording is limited to 64. During the operation of the function, the pre-fault signals are preserved for the time duration as defined by the parameter “PreFault”. The fault duration is limited by the parameter “MaxFault” but if the triggering signal resets earlier, this section is shorter. The post-fault signals are preserved for the time duration as defined by the parameter “PostFault”. During or after the running of the recording, the triggering condition must be reset for a new recording procedure to start.

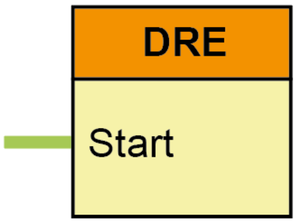
The records are stored in standard COMTRADE format:

- The configuration is defined by the file .cfg
- The data are stored in the file .dat
- Plain text comments can be written in the file .inf.

The procedure for downloading the records includes a downloading of a single compressed. zip-file. Downloading can be initiated from a web browser tool or from the software tools.This procedure assures that the three component files (.cfg, .dat and .inf) are stored in the same location. The evaluation can be performed using any COMTRADE evaluator software, e.g. Arcteq’s AQview software. Consult your nearest Arcteq representative for availability.

The function block of the disturbance recorder function is shown in figure bellow. This block shows all binary input and output status signals that are applicable in the AQtivate 300 software.

Figure. 6.4.8 - 101. The function block of the disturbance recorder function.



The binary input and output status signals of the dead line detection function are listed intables below.

Table. 6.4.8 - 66. The binary input signal of the function.

Binary status signal	Explanation
DRE_Start_GrO_	Output status of a graphic equation defined by the user to start the disturbance recorder function.

Table. 6.4.8 - 67. Setting parameters.

Parameter	Setting value/range	Step	Default	Description
Operation	On Off	-	On	Function enbaling / disabling.
PreFault	100…500 ms	1 ms	200 ms	Pre triggering time included in the recording.
PostFault	100…1 000 ms	1 ms	200 ms	Post fault time included in the recording.
MaxFault	500…10 000 ms	1 ms	1 000 ms	Overall maximum time limit in the recording.

6.4.9 Event recorder

The events of the device and those of the protection functions are recorded with a time stamp of 1 ms time resolution. This information with indication of the generating function can be checked on the touch-screen of the device in the “Events” page, or using an Internet browser of a connected computer.

Table. 6.4.9 - 68. List of events.

Event	Explanation
Voltage transformer supervision function (VTS)	
VT Failure	Error signal of the voltage transformer supervision function
Common	
Mode of device	Mode of device
Health of device	Health of device
Three-phase instantaneous overcurrent protection function (IOC50)	
Trip L1	Trip command in phase L1
Trip L2	Trip command in phase L2
Trip L3	Trip command in phase L3
General Trip	General trip command
Residual instantaneous overcurrent protection function (IOC50N)	
General Trip	General trip command
Directional overcurrent protection function (TOC67) low setting stage	
Start L1	Start signal in phase L1
Start L2	Start signal in phase L2
Start L3	Start signal in phase L3
Start	Start signal
Trip	Trip command

Directional overcurrent protection function (TOC67) high setting stage	
Start L1	Start signal in phase L1
Start L2	Start signal in phase L2
Start L3	Start signal in phase L3
Start	Start signal
Trip	Trip command
Residual directional overcurrent protection function (TOC67N) low setting stage	
Start	Start signal
Trip	Trip command
Residual directional overcurrent protection function (TOC67N) high setting stage	
Start	Start signal
Trip	Trip command
Line thermal protection function (TTR49L)	
Alarm	Line thermal protection alarm signal
General Trip	Line thermal protection trip command
Current unbalance protection function	
General Start	General Start
General Trip	General Trip
Current unbalance protection function	
2.Harm Restraint	Second harmonic restraint
Definite time overvoltage protection function (TOV59)	
Low Start L1	Low setting stage start signal in phase L1
Low Start L2	Low setting stage start signal in phase L2
Low Start L3	Low setting stage start signal in phase L3
Low General Start	Low setting stage general start signal
Low General Trip	Low setting stage general trip command
High Start L1	High setting stage start signal in phase L1
High Start L2	High setting stage start signal in phase L2
High Start L3	High setting stage start signal in phase L3
High General Start	High setting stage general start signal
High General Trip	High setting stage general trip command
Definite time undervoltage protection function (TUV27)	

Low Start L1	Low setting stage start signal in phase L1
Low Start L2	Low setting stage start signal in phase L2
Low Start L3	Low setting stage start signal in phase L3
Low General Start	Low setting stage general start signal
Low General Trip	Low setting stage general trip command
High Start L1	High setting stage start signal in phase L1
High Start L2	High setting stage start signal in phase L2
High Start L3	High setting stage start signal in phase L3
High General Start	High setting stage general start signal
High General Trip	High setting stage general trip command
Overfrequency protection function (TOF81)	
Low General Start	Low setting stage general start signal
Low General Trip	Low setting stage general trip command
High General Start	High setting stage general start signal
High General Trip	High setting stage general trip command
Underfrequency protection function (TUF81)	
Low General Start	Low setting stage general start signal
Low General Trip	Low setting stage general trip command
High General Start	High setting stage general start signal
High General Trip	High setting stage general trip command
Rate-of-change of frequency protection function (FRC81)	
Low General Start	Low setting stage general start signal
Low General Trip	Low setting stage general trip command
High General Start	High setting stage general start signal
High General Trip	High setting stage general trip command
Breaker failure protection function (BRF50)	
Backup Trip	Repeated trip command
Trip logic function (TRC94)	
General Trip	General Trip
Synchrocheck function (SYN25)	
Released Auto	The function releases automatic close command
In progress Auto	The automatic close command is in progress

Close_Auto	Close command in automatic mode of operation
Released Man	The function releases manual close command
In progress Man	The manual close command is in progress
Close_Man	Close command in manual mode of operation
Automatic reclosing function (REC79)	
Blocked	Blocked state of the automatic reclosing function
Close Command	Close command of the automatic reclosing function
Status	State of the automatic reclosing function
Actual cycle	Running cycle of the automatic reclosing function
Final Trip	Definite trip command at the end of the automatic reclosing cycles
Measurement function (MXU)	
Current L1	Current violation in phase L1
Current L2	Current violation in phase L2
Current L3	Current violation in phase L3
Voltage L12	Voltage violation in phase L12
Voltage L23	Voltage violation in phase L23
Voltage L31	Voltage violation in phase L31
Active Power – P	Active Power – P violation
Reactive Power – Q	Reactive Power – Q violation
Apparent Power – S	Apparent Power – S violation
Frequency	Frequency violation
CB1Pol	
Status value	Status of the circuit breaker
Enable Close	Close command is enabled
Enable Open	Open command is enabled
Local	Local mode of operation
Operation counter	Operation counter
CB OPCap	
Disconnector Line	
Status value	Status of the circuit breaker
Enable Close	Close command is enabled
Enable Open	Open command is enabled

Local	Local mode of operation
Operation counter	Operation counter
DC OPCap	
Disconnector Earth	
Status value	Status of the earthing switch
Enable Close	Close command is enabled
Enable Open	Open command is enabled
Local	Local mode of operation
Operation counter	Operation counter
DC OPCap	
Disconnector Bus	
Status value	Status of the bus disconnector
Enable Close	Close command is enabled
Enable Open	Open command is enabled
Local	Local mode of operation
Operation counter	Operation counter
DC OPCap	

6.4.10 Measured values

The measured values can be checked on the touch-screen of the device in the “On-line functions” page, or using an Internet browser of a connected computer. The displayed values are secondary voltages and currents, except the block “Line measurement”. This specific block displays the measured values in primary units, using the VT and CT primary value settings.

Table. 6.4.10 - 69. Analogue value measurements.

Analog value	Explanation
VT4 module	
Voltage Ch – U1	RMS value of the Fourier fundamental harmonic voltage component in phase L1
Angle Ch – U1	Phase angle of the Fourier fundamental harmonic voltage component in phase L1*
Voltage Ch – U2	RMS value of the Fourier fundamental harmonic voltage component in phase L2
Angle Ch – U2	Phase angle of the Fourier fundamental harmonic voltage component in phase L2*
Voltage Ch – U3	RMS value of the Fourier fundamental harmonic voltage component in phase L3
Angle Ch – U3	Phase angle of the Fourier fundamental harmonic voltage component in phase L3*
Voltage Ch – U4	RMS value of the Fourier fundamental harmonic voltage component in Channel U4

Analog value	Explanation
Angle Ch – U4	Phase angle of the Fourier fundamental harmonic voltage component in Channel U4*
CT4 module	
Current Ch – I1	RMS value of the Fourier fundamental harmonic current component in phase L1
Angle Ch – I1	Phase angle of the Fourier fundamental harmonic current component in phase L1*
Current Ch – I2	RMS value of the Fourier fundamental harmonic current component in phase L2
Angle Ch – I2	Phase angle of the Fourier fundamental harmonic current component in phase L2*
Current Ch – I3	RMS value of the Fourier fundamental harmonic current component in phase L3
Angle Ch – I3	Phase angle of the Fourier fundamental harmonic current component in phase L3*
Current Ch – I4	RMS value of the Fourier fundamental harmonic current component in Channel I4
Angle Ch – I4	Phase angle of the Fourier fundamental harmonic current component in Channel I4*
Values for the directional measurement	
L12 loop R	Resistance of loop L1L2
L12 loop X	Reactance of loop L1L2
L23 loop R	Resistance of loop L2L3
L23 loop X	Reactance of loop L2L3
L31 loop R	Resistance of loop L3L1
L31 loop X	Reactance of loop L3L1
Line thermal protection	
Calc. Temperature	Calculated line temperature
Synchrocheck	
Voltage Diff	Voltage magnitude difference
Frequency Diff	Frequency difference
Angle Diff	Angle difference
Line measurement (here the displayed information means primary value)	
Active Power – P	Three-phase active power
Reactive Power – Q	Three-phase reactive power
Apparent Power – S	Three-phase power based on true RMS voltage and current measurement
Current L1	True RMS value of the current in phase L1
Current L2	True RMS value of the current in phase L2
Current L3	True RMS value of the current in phase L3
Voltage L1	True RMS value of the voltage in phase L1

Analog value	Explanation
Voltage L2	True RMS value of the voltage in phase L2
Voltage L3	True RMS value of the voltage in phase L3
Voltage L12	True RMS value of the voltage in phase L1L2
Voltage L23	True RMS value of the voltage in phase L2L3
Voltage L31	True RMS value of the voltage in phase L3L1
Frequency	Frequency

6.4.11 Status monitoring for switching devices

The status of circuit breakers and the disconnectors (line disconnector, bus disconnector, earthing switch) are monitored continuously. This function also enables operation of these devices using the screen of the local LCD. To do this the user can define the user screen and the active scheme.

6.4.12 Trip circuit supervision

All four fast acting trip contacts contain build-in trip circuit supervision function. The output voltage of the circuit is 5V (+-1V). The pickup resistance is 2.5kohm (+-1kohm).

CAUTION!
Pay attention to the polarity of the auxiliary voltage supply as outputs are polarity dependent.

7 System integration

The AQ T3xx contains two ports for communicating to upper level supervisory system and one for process bus communication. The physical media or the ports can be either serial fiber optic or RJ 45 or Ethernet fiber optic.

The AQ T3xx Transformer protection IED communicates using IEC 61850, IEC 101, IEC 103, IEC 104, Modbus RTU, DNP3.0 and SPA protocols. For details of each protocol refer to respective interoperability lists.

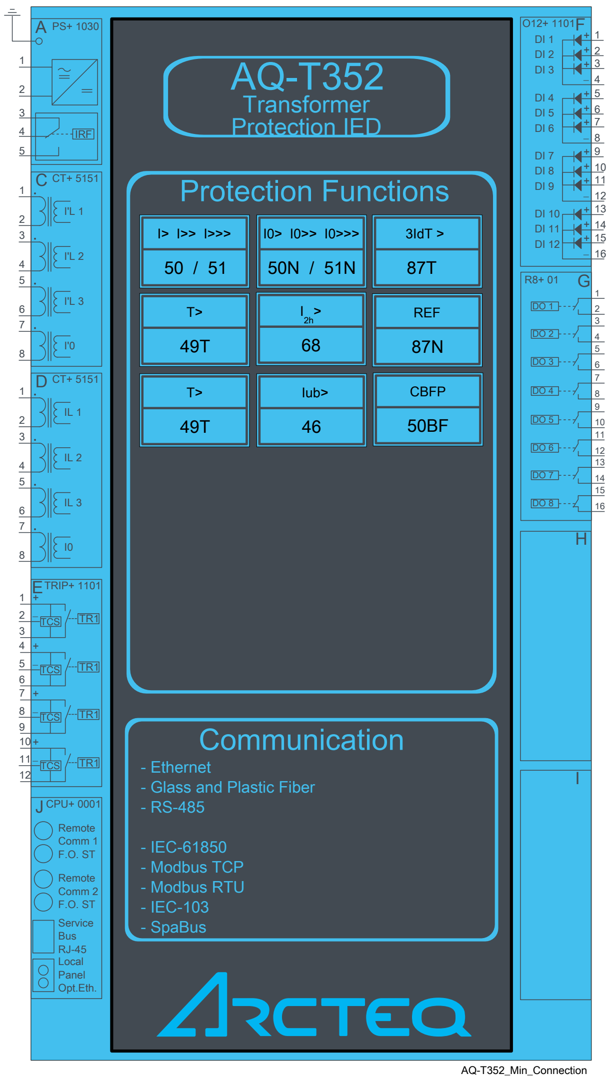
8 Connections

8.1 Block diagrams

> NOTICE!
> The structure of both AQ-T352 (the half-rack version) and AQ-T392 (the full rack version) is the same, except AQ-T392 has more option card slots available.
> The structure of both AQ-T353 (the half-rack version) and AQ-T393 (the full rack version) is the same, except AQ-T393 has more option card slots available.

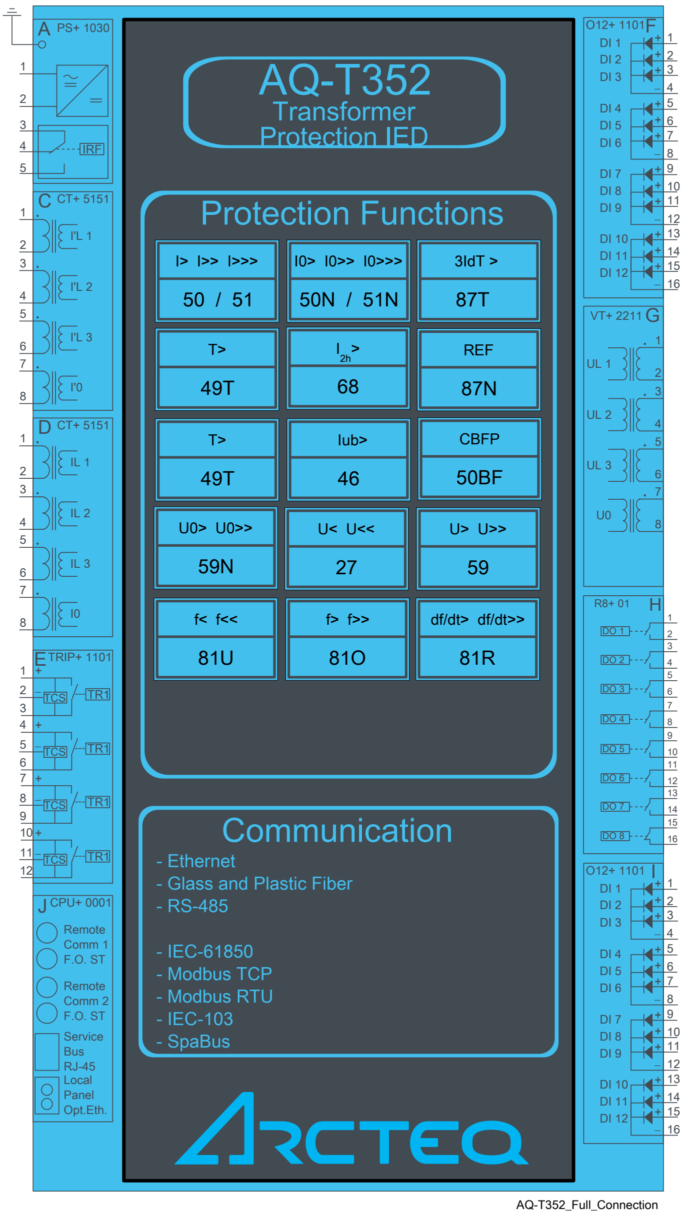
Block diagram of AQ-T352 with minimum options

Figure. 8.1 - 102. Block diagram of AQ-T352 with minimum options installed.



Block diagram of AQ-T352 with all options

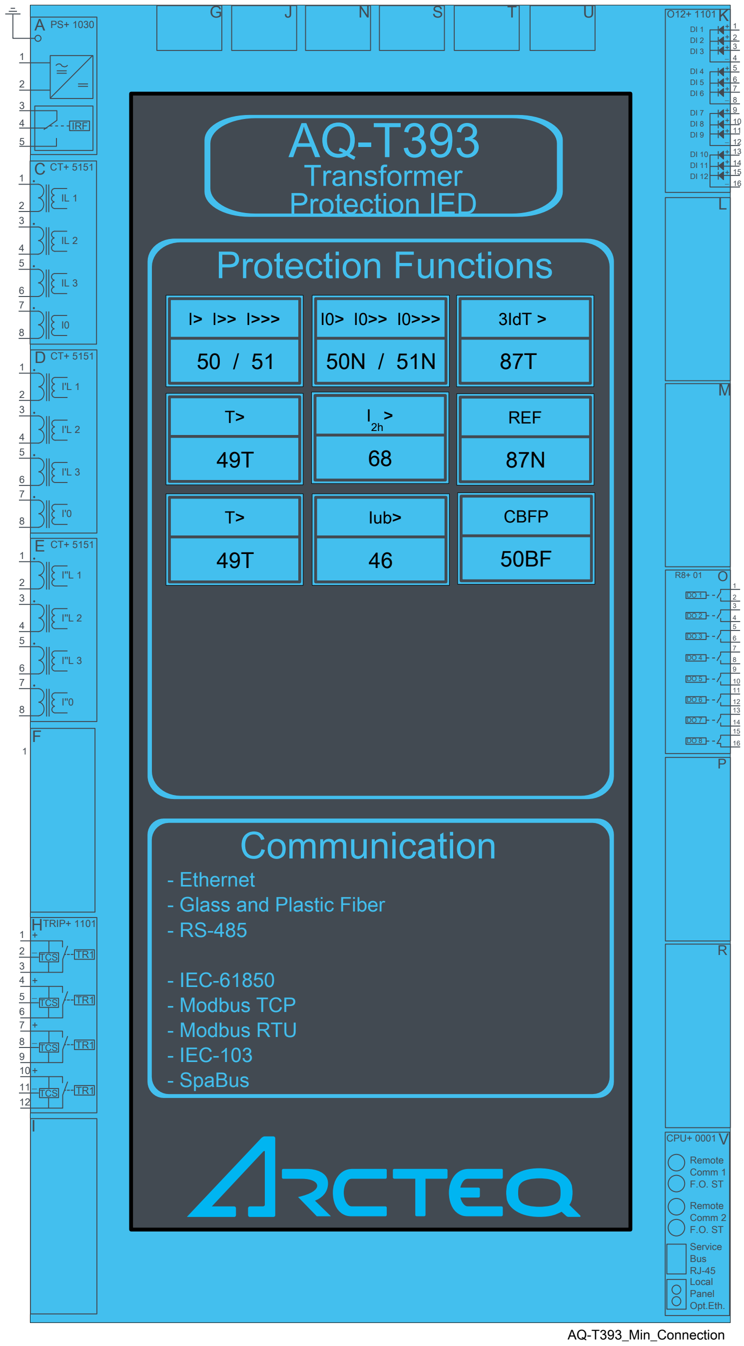
Figure. 8.1 - 103. Block diagram of AQ-T352 with all options installed.



> **NOTICE!**
> If voltage measurement option is installed into the IED, voltage based protection functions are available. For the E and F slots can be installed either DI or DO options.

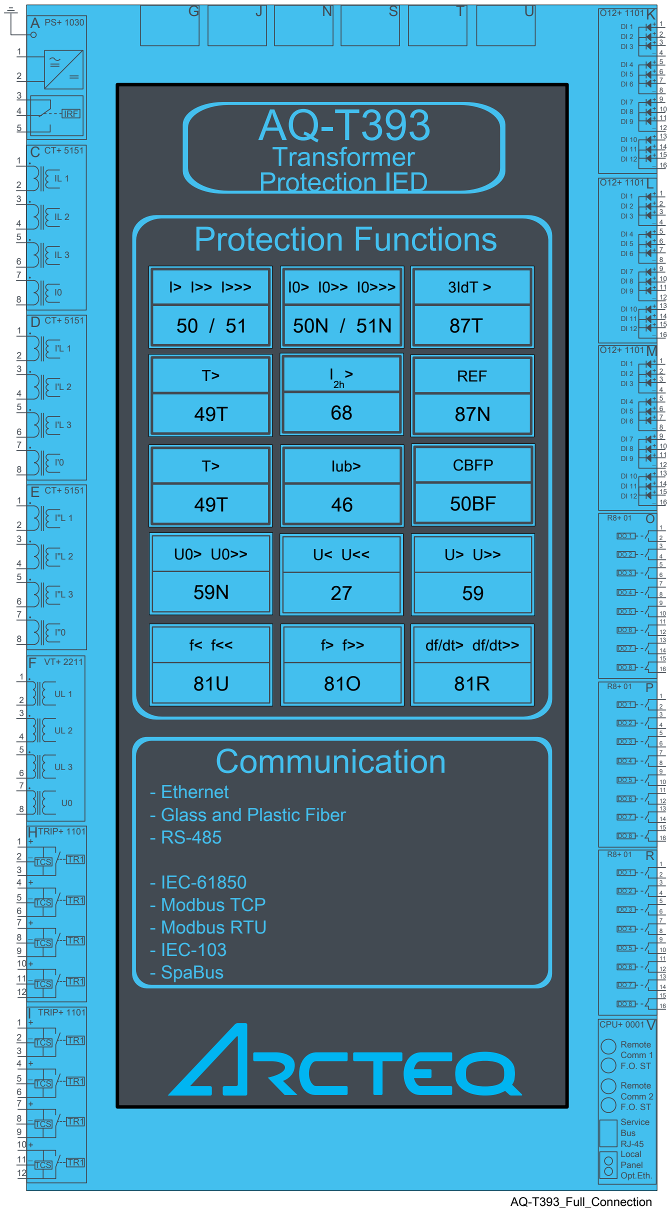
Block diagram of AQ-T393 with minimum options

Figure. 8.1 - 104. Block diagram of AQ-T393 with minimum options installed.



Block diagram of AQ-T393 with all options

Figure. 8.1 - 105. Block diagram of AQ-T393 with all options installed.



> **NOTICE!**
> IED has six spare slots available for option cards which are not used in this example.

8.2 Connection example

Figure. 8.2 - 106. Connection example of AQ-T352 transformer protection IED.

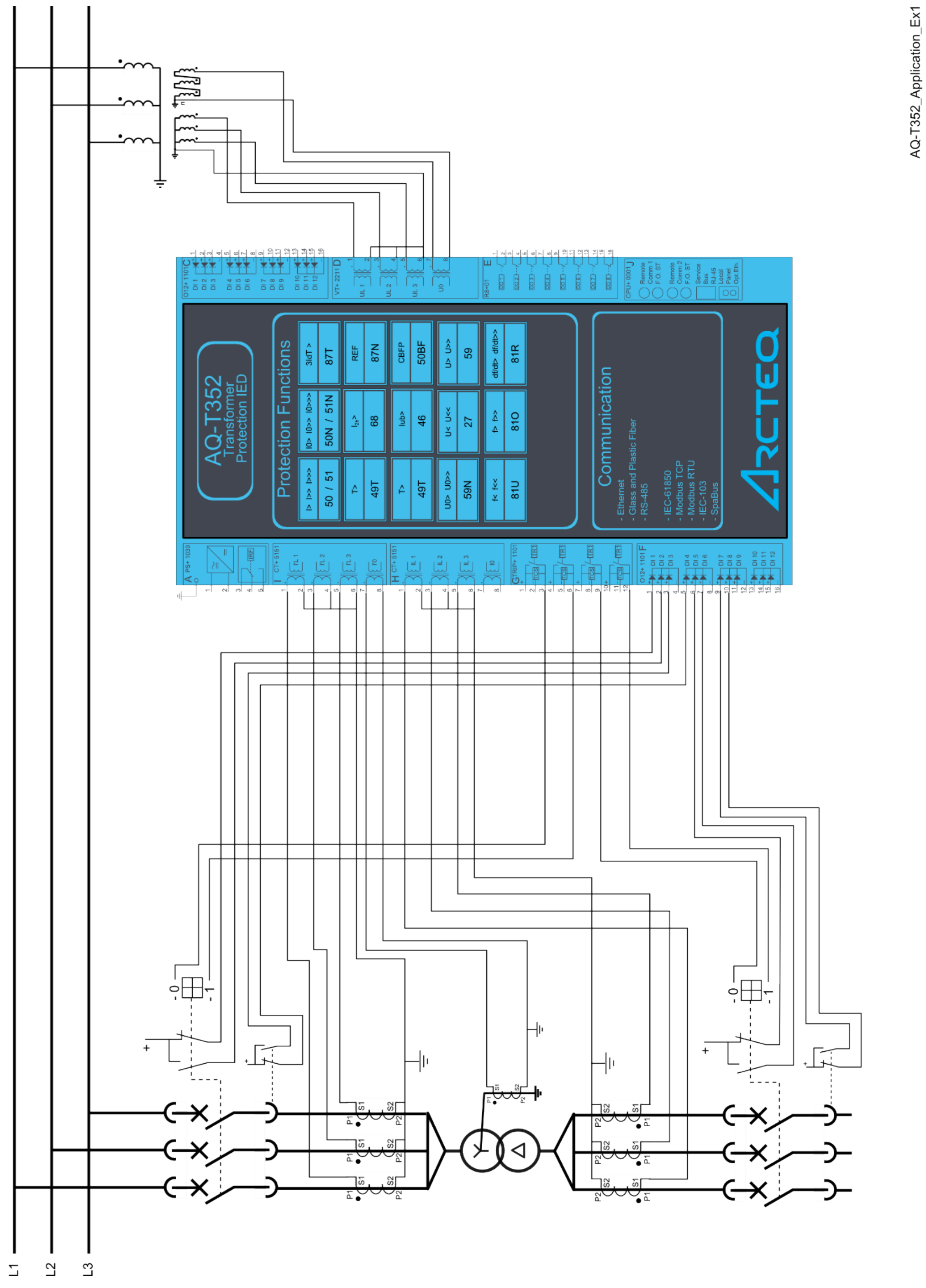
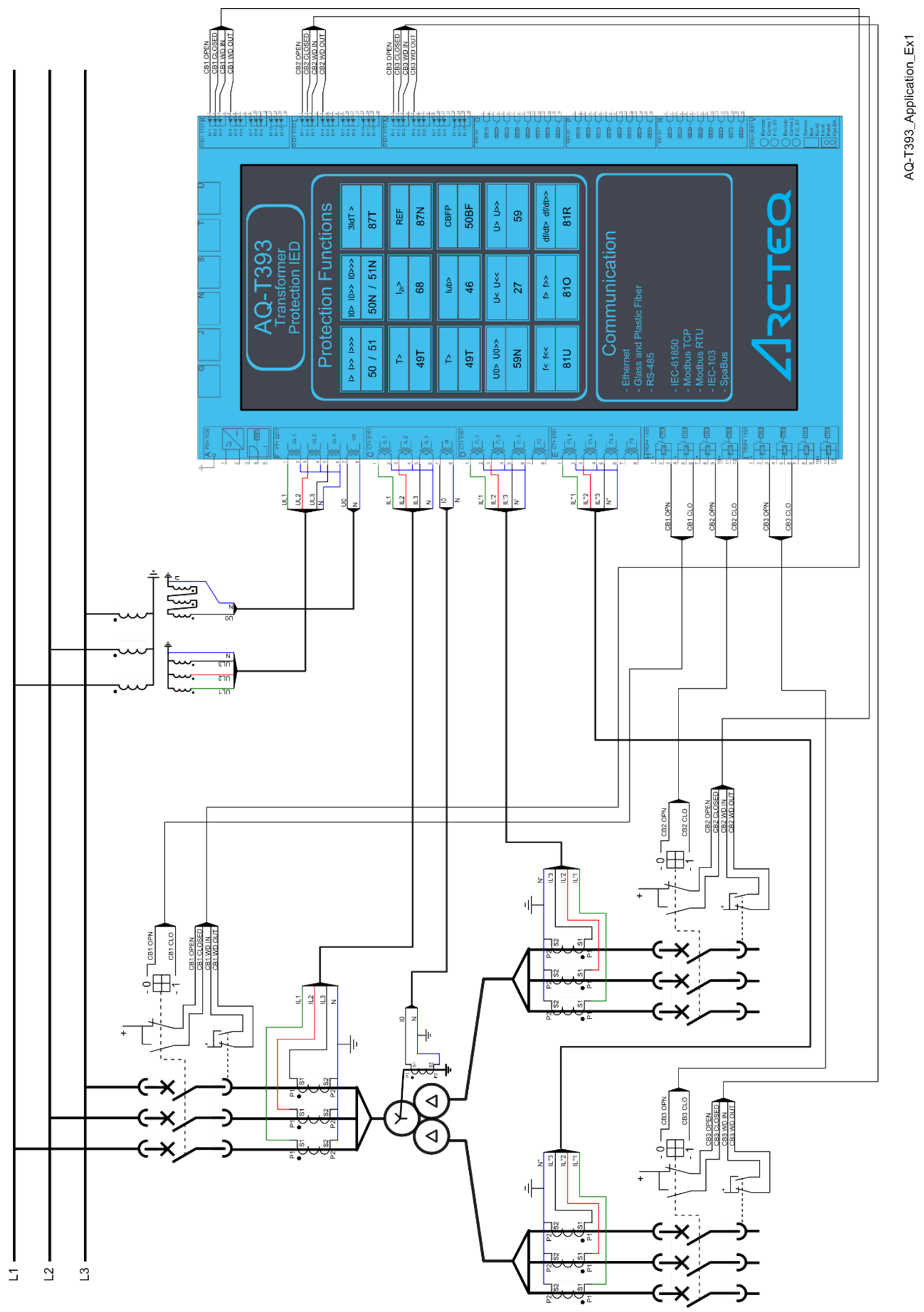


Figure. 8.2 - 107. Connection example of AQ-T393 transformer protection IED.



9 Construction and installation

9.1 Construction

Contruction and installation of AQ-T352

The AQ-T352 transformer protection IED consists of hardware modules. Due to modular structure optional positions for the slots can be user defined in the ordering of the IED to include I/O modules and other types of additional modules. An example module arrangement configuration of AQ-T352 is shown in the figure below. Visit https://configurator.arcteq.fi/ to see all of the available options.

Figure. 9.1 - 108. An example module arrangement configuration for the AQ-T352 IED.

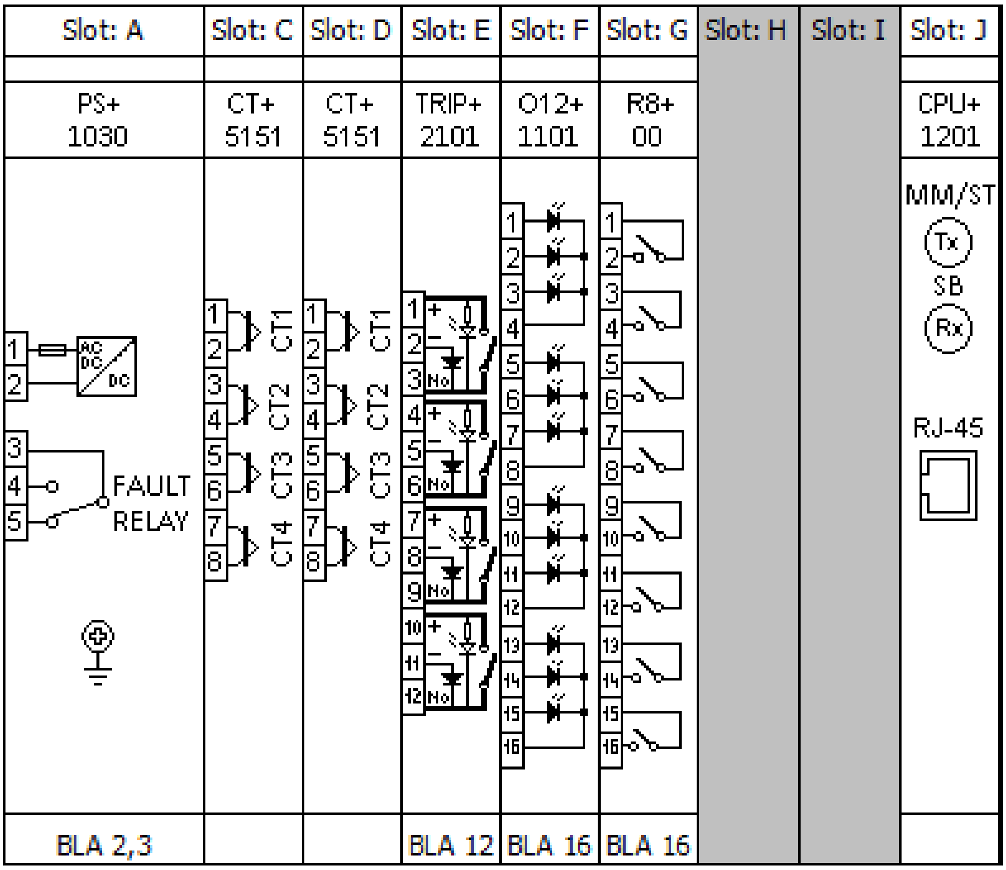


Table. 9.1 - 70. Descriptions of the hardware modules for AQ-T352.

Position	Module identifier	Explanation
A–B	PS+ 1030	Power supply unit, 85…265 V AC, 88…300 V DC
C	CT+ 5151	Analog current input module for primary currents
D	CT+ 5151	Analog voltage input module for secondary currents
E	TRIP+ 2101	Trip relay output module, 4 tripping contacts
F	O12+ 1101	Binary input module, 12 inputs

Position	Module identifier	Explanation
G	R8+ 00	Binary output module, 8 output contacts
J	CPU+ 1201	Processor and communication module
H, I	Spare	—

Contruction and installation of AQ-T392

The AQ-T392 transformer protection IED consists of hardware modules. Due to modular structure optional positions for the slots can be user defined in the ordering of the IED to include I/O modules and other types of additional modules. An example module arrangement configuration of AQ-T392 is shown in the figure below. Visit https://configurator.arcteq.fi/ to see all of the available options.

Figure. 9.1 - 109. An example module arrangement configuration for the AQ-T392 IED.

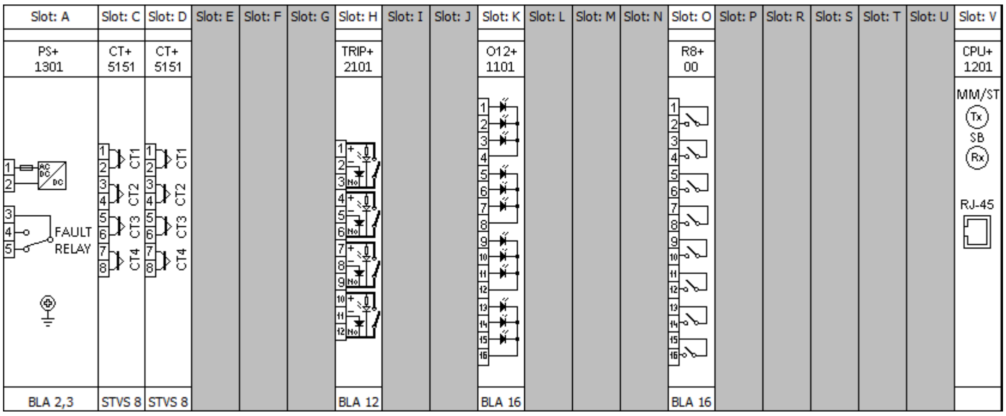


Table. 9.1 - 71. Descriptions of the hardware modules for AQ-T392.

Position	Module identifier	Explanation
A–B	PS+ 1030	Power supply unit, 85…265 V AC, 88…300 V DC
C	CT+ 5151	Analog current input module for primary currents
D	CT+ 5151	Analog voltage input module for secondary currents
H	TRIP+ 2101	Trip relay output module, 4 tripping contacts
K	O12+ 1101	Binary input module, 12 inputs
O	R8+ 00	Binary output module, 8 output contacts
V	CPU+ 1201	Processor and communication module
E–G, I–J, L–N, P–U	Spare	—

Contruction and installation of AQ-T393

NOTICE!
Please note that while the construction below is for AQ-T393, it also applies to AQ-T353 although the latter has fewer empty slots for additional I/O modules.

The AQ-T393 transformer protection IED consists of hardware modules. Due to modular structure optional positions for the slots can be user defined in the ordering of the IED to include I/O modules and other types of additional modules. An example module arrangement configuration of AQ-T393 is shown in the figure below. Visit https://configurator.arcteq.fi/ to see all of the available options.

Figure. 9.1 - 110. An example module arrangement configuration for the AQ-T393 IED.

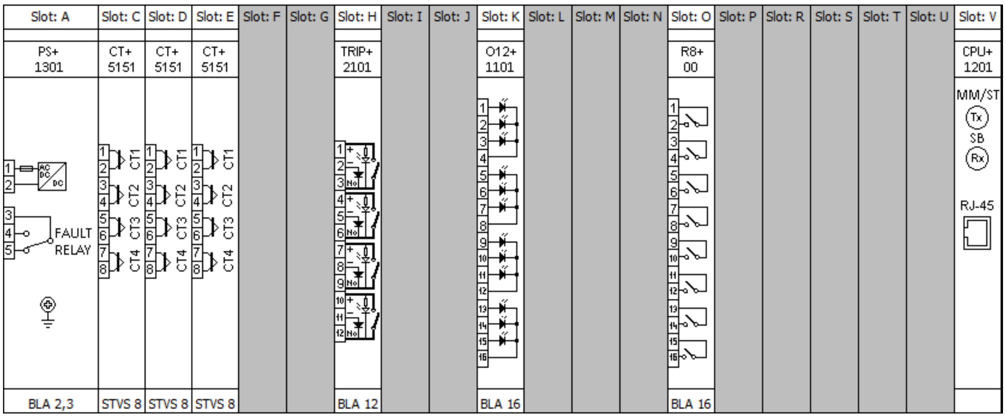


Table. 9.1 - 72. Descriptions of the hardware modules for AQ-T393.

Position	Module identifier	Explanation
A–B	PS+ 1030	Power supply unit, 85…265 V AC, 88…300 V DC
C	CT+ 5151	Analog current input module for primary currents
D	CT+ 5151	Analog voltage input module for secondary currents
E	CT+ 5151	Analog voltage input module for tertiary currents
H	TRIP+ 2101	Trip relay output module, 4 tripping contacts
K	O12+ 1101	Binary input module, 12 inputs
O	R8+ 00	Binary output module, 8 output contacts
V	CPU+ 1201	Processor and communication module
F–G, I–J, L–N, P–U	Spare	—

9.2 CPU module

The CPU module contains all the protection, control and communication functions of the AQ-x3xx device. Dual 500 MHz high-performance Analog Devices Blackfin processors separates relay functions (RDSP) from communication and HMI functions (CDSP). Reliable communication between processors is performed via high-speed synchronous serial internal bus (SPORT).

Each processor has its own operative memory such as SDRAM and flash memories for configuration, parameter and firmware storage. CDSP's operating system (uClinux) utilizes a robust JFFS flash file system, which enables fail-safe operation and the storage of disturbance record files, configuration and parameters.

After power-up the RDSP processor starts up with the previously saved configuration and parameters. Generally, the power-up procedure for the RDSP and relay functions takes approx. 1 sec. That is to say, it is ready to trip within this time. CDSP's start-up procedure is longer, because its operating system needs time to build its file system, initializing user applications such as HMI functions and the IEC 61850 software stack.

The built-in 5- port Ethernet switch allows the AQ-x3xx device to connect to IP/Ethernet- based networks. The following Ethernet ports are available:

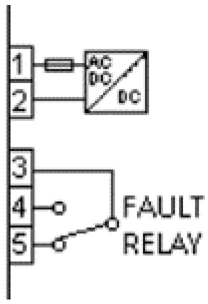
- Station bus (100Base-FX Ethernet).
- Redundant Station bus (100Base-FX Ethernet).
- Process bus (100Base-FX Ethernet).
- EOB (Ethernet over Board) user interface.
- Optional 100Base-TX port via RJ-45 connector.

Other communication:

- R422/RS485/RS232 interfaces.
- Plastic or glass fiber interfaces to support legacy protocols.
- Process-bus communication controller on COM+ card.

9.3 Power supply module

Figure. 9.3 - 111. Connector allocation of the 30 W power supply unit.



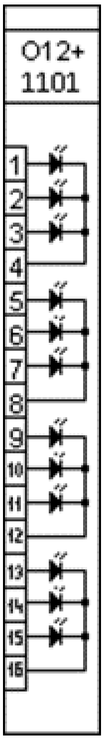
The power supply module converts primary AC and/or DC voltage to required system voltages. Redundant power supply cards extend system availability in case of the outage of any power source and can be ordered separately if required.

Main features of the power supply module:

- 30 W input.
- Maximum 100 ms power interruption time: measured at nominal input voltage with nominal power consumption.
- IED system fault contacts (NC and NO): device fault contact and also assignable to user functions. All the three relay contact points (NO, NC, COM) are accessible to users 80…300 V DC input range, AC power is also supported.
- Redundant applications which require two independent power supply modules can be ordered optionally.
- On-board self-supervisory circuits: temperature and voltage monitors.
- Short-circuit-protected outputs.
- Efficiency: >70 %.
- Passive heat sink cooling.
- Early power failure indication signals to the CPU the possibility of power outage, thus the CPU has enough time to save the necessary data to non-volatile memory.

9.4 Binary input module(s)

Figure. 9.4 - 112. The binary input module O12+ 1101.



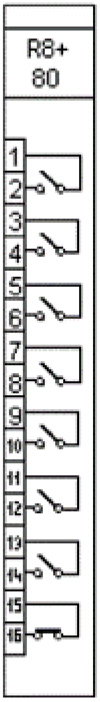
The inputs are galvanic isolated and the module converts high-voltage signals to the voltagelevel and format of the internal circuits. This module is also used as an external IRIG-B synchronization input. Dedicated synchronization input (input channel 1) is used for this purpose.

The binary input modules are:

- Rated input voltage: 110/220 V DC.
- Clamp voltage: falling 0.75 Un, rising 0.78 Un.
- Digitally filtered per channel.
- Current drain approx.: 2 mA per channel.
- 12 inputs.
- IRIG-B timing and synchronization input.

9.5 Binary output module(s)

Figure. 9.5 - 113. The binary output module R8+ 80.



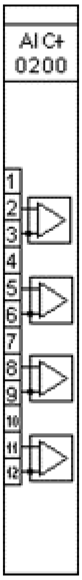
The signaling output modules can be ordered as 8 relay outputs with dry contacts.

The binary output modules are:

- Rated voltage: 250 V AC/DC.
- Continuous carry: 8 A.
- Breaking capacity, (L/R = 40 ms)at 220 V DC: 0.2 A
- 8 contacts: 7 NO and 1 NC

9.6 Milliampere module

Figure. 9.6 - 114. The milliampere (mA) input module AIC +0200.



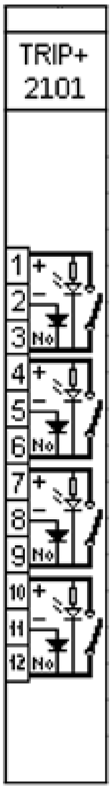
The analog input module accepts transducers current outputs. The AIC module can measure unipolar and bipolar current values in wide ranges.

Main features:

- Number of channels: 4
- Measurement method: 2 wire inputs with optional 15V excitation
- Relative accuracy: ± 0.5 % ± 1 digit
- Measurement ranges: ± 20 mA (typical 0-20, 4-20 mA), Rload = 56 Ω

9.7 Tripping module

Figure. 9.7 - 115. The tripping module TRIP+ 2101.



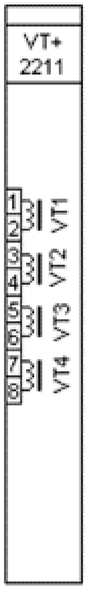
The tripping module applies direct control of a circuit breaker. The module provides fast operation and is rated for heavy duty controlling.

The main characteristics of the trip module:

- 4 independent tripping circuits.
- High-speed operation.
- Rated voltage: 110 V, 220 V DC.
- Continuous carry: 8 A.
- Making capacity: 0.5 s, 30 A.
- Breaking capacity (L/R = 40 ms) at 220 V DC: 4A.
- Trip circuit supervision for each trip contact.

9.8 Voltage measurement module

Figure. 9.8 - 116. The voltage measurement module VT+ 2211.



For voltage related functions (over- /under -voltage, directional functions, distance function,power functions) or disturbance recorder functionality this module is needed. This module also has capability for frequency measurement.

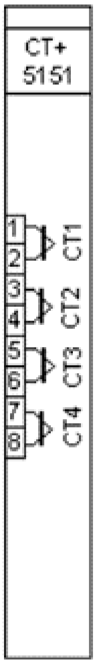
For capacitive voltage measurement of the synchrocheck reference, the voltage measurement module can be ordered with reduced burden in channel VT4. In this module the burden is < 50 mVA.

The main characteristics of the voltage measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Selectable rated voltage (Un): 100/√3, 100 V, 200/√3, 200 V by parameter.
- Voltage measuring range: 0.05 Un – 1.2 Un.
- Continuous voltage withstand: 250 V.
- Power consumption of voltage input: ≤1 VA at 200 V (with special CVT module the burden is < 50 mVA for VT4 channel).
- Relative accuracy: ±0.5 %.
- Frequency measurement range: ±0.01 % at Ux 25 % of rated voltage.
- Measurement of phase angle: 0.5° Ux 25 % of rated voltage.

9.9 Current measurement module

Figure. 9.9 - 117. Connector allocation of the current measurement module.



Current measurement module is used for measuring current transformer output current. Module includes three phase current inputs and one zero sequence current input. The nominal rated current of the input can be selected with a software parameter either 1 A or 5 A.

The main chracteristics of the current measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Electronic iron-core flux compensation.
- Low consumption: ≤0.1 VA at rated current.
- Current measuring range: 35 x In.
- Selectable rated current 1 A/5 A by parameter.
- Thermal withstand:
    - 20 A (continuously)
    - 500 A (for 1 s)
    - 1200 A (for 10 ms)
- Relative accuracy: ±0.5 %.
- Measurement of phase angle: 0.5º, Ix 10 % rated current.

9.10 Installation and dimensions

Figure. 9.10 - 118. Dimensions of AQ-x35x IED.

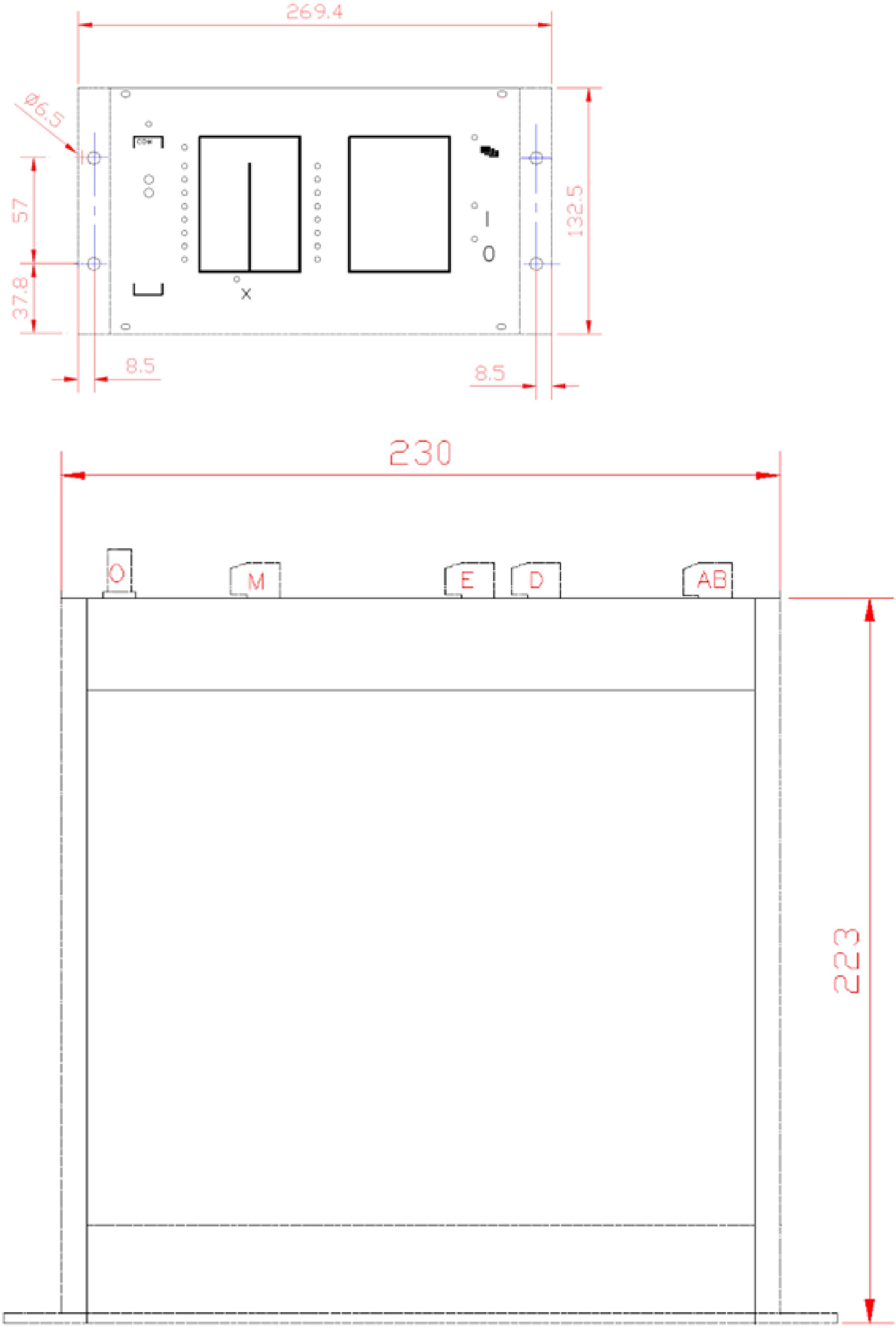


Figure. 9.10 - 119. Panel cut-out and spacing of AQ-x35x IED.

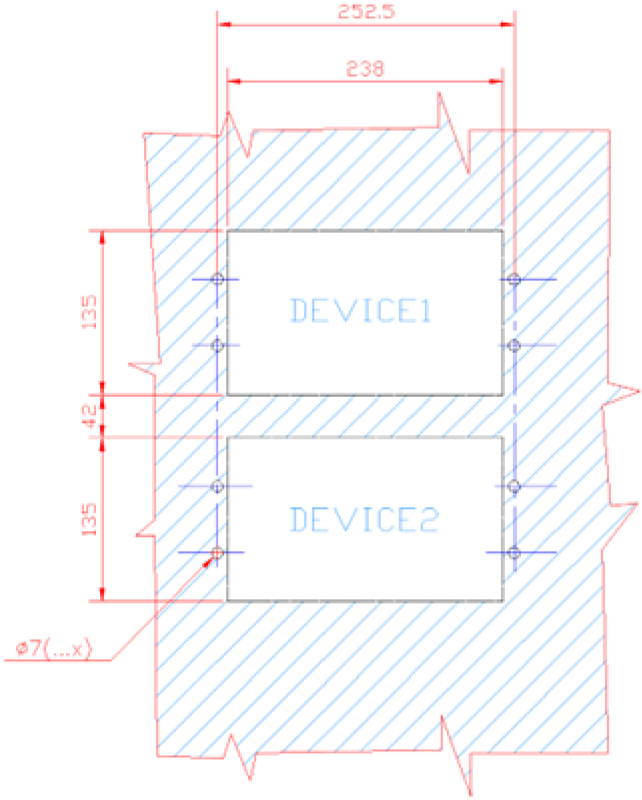


Figure. 9.10 - 120. Dimensions of AQ-x39x IED.

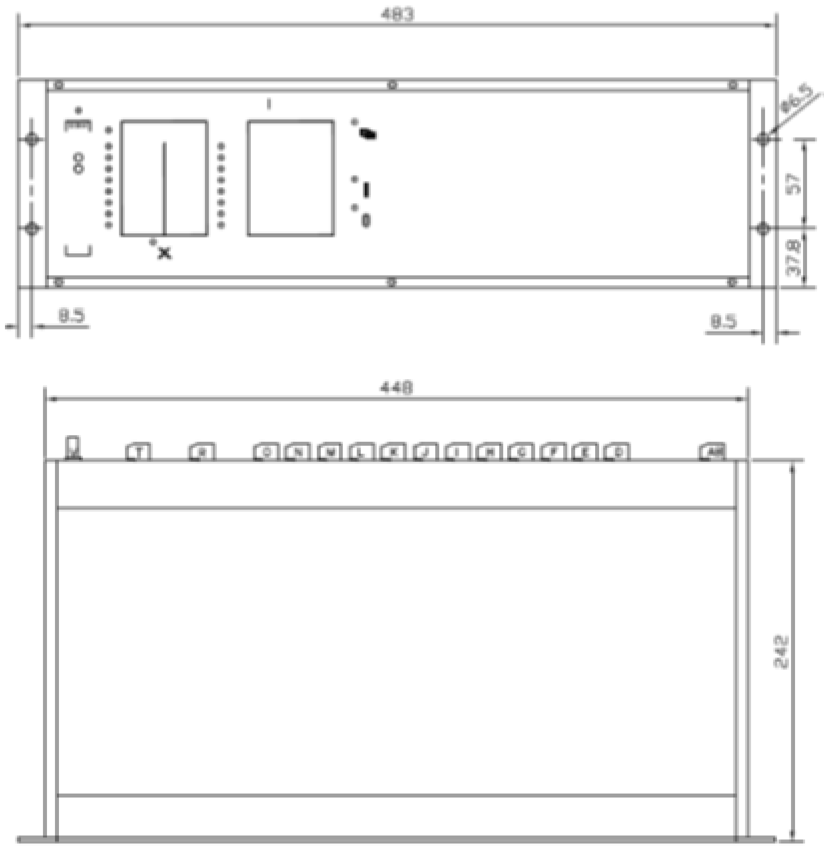
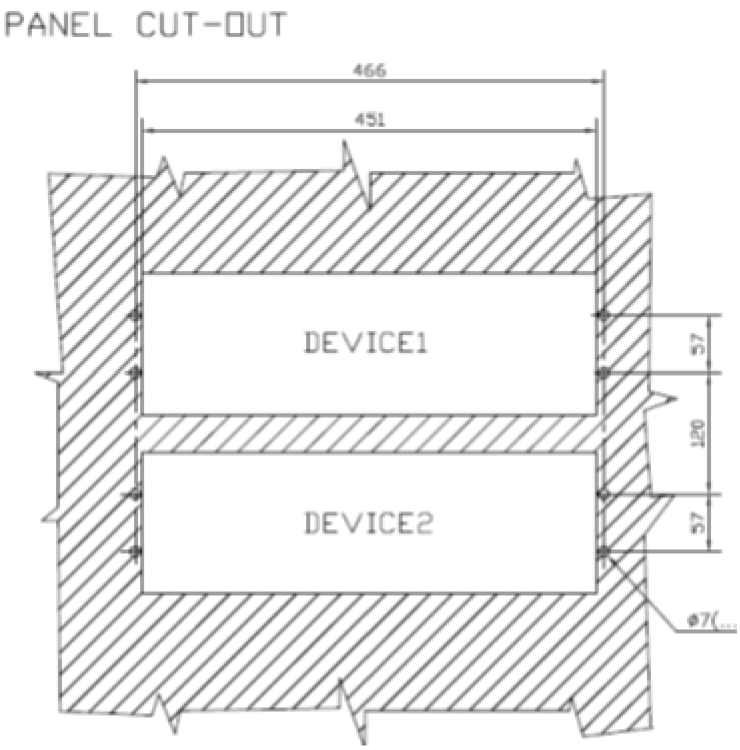


Figure. 9.10 - 121. Panel cut-out and spacing of AQ-x39x IED.



10 Technical data

10.1 Protection functions

Breaker failure protection function CBFP, (50BF)

Current inaccuracy	<2 %
Re-trip time	Approx. 15ms
Operation time inaccuracy	± 5ms
Current reset time	20ms

Current unbalance protection function (60)

Pick-up starting inaccuracy at In	< 2 %
Reset ratio	0,95
Operate time	70 ms

Three-phase instantaneous overcurrent protection I> (50)

Operating characteristic	Instantaneous
Pick-up current inaccuracy	<2%
Reset ratio	0.95
Operate time at 2*In Peak value calculation Fourier calculation	 <15 ms <25 ms
Reset time	16 – 25 ms
Transient overreach Peak value calculation Fourier calculation	 80 % 2 %

Three-phase time overcurrent protection I> (50/51)

Pick-up current inaccuracy	< 2%
Operation time inaccuracy	±5% or ±15ms
Reset ratio	0.95
Minimum operating time with IDMT	35ms
Reset time	Approx 35ms
Transient overreach	2 %

Pickup time	25 – 30ms

Residual instantaneous overcurrent protection I0> (50N)

Operating characteristic	Instantaneous
Picku-up current inaccuracy	<2%
Reset ratio	0.95
Operate time at 2*In Peak value calculation Fourier calculation	<15 ms <25 ms
Reset time	16 – 25 ms
Transient overreach Peak value calculation Fourier calculation	80 % 2 %

Residual time overcurrent protection I0> (51N)

Pick-up current inaccuracy	< 2%
Operation time inaccuracy	±5% or ±15ms
Reset ratio	0.95
Minimum operating time with IDMT	35ms
Reset time	Approx 35ms
Transient overreach	2 %
Pickup time	25 – 30ms

Overvoltage protection function U> (59)

Pick-up starting inaccuracy	< 0,5 %
Reset time U> → Un U> → 0	50 ms 40 ms
Operation time inaccuracy	± 15 ms

Undervoltage protection function U< (27)

Pick-up starting inaccuracy	< 0.5 %
Reset time: • U> → Un • U> → 0	50 ms 40 ms
Operate time inaccuracy	+15 ms

Residual overvoltage protection function U0> (59N)

Pick-up starting inaccuracy	< 0,5 %
Reset time U> → Un U> → 0	50 ms 40 ms
Operate time inaccuracy	± 15 ms

Overfrequency protection function f> (81O)

Operating range	40 - 60 Hz
Operating range inaccuracy	30mHz
Effective range inaccuracy	2mHz
Minimum operating time	100ms
Operation time inaccuracy	± 10ms
Reset ratio	0,99

Underfrequency protection function f< (81U)

Operating range	40 - 70 Hz
Operating range inaccuracy	30 mHz
Effective range inaccuracy	2 mHz
Minimum operating time	140 ms
Operation time inaccuracy	+10 ms
Reset ratio	0.99

Rate-of-change of frequency protection function df/dt> (81R)

Effective operating range	-5...+5 Hz/s
Pick-up inaccuracy	0.01 Hz/s
Minimum operating time	140 ms
Operation time inaccuracy	+15 ms

Thermal overload protection function T> (49)

Operation time inaccuracy at I> 1.2*Itrip	3 % or +20 ms

Overexcitation/volts per hertz protection V/Hz, (24)

Frequency range	10…70Hz

Voltage range	10…170V secondary
Voltage measurement inaccuracy	<1% (0.5 – 1.2xUn)
Frequency measurement inaccuracy	<1% (0.8 – 1.2xfn)

Differential protection (87)

Operating characteristic	2 breakpoint
Characteristics inaccuracy	<2%
Reset ratio	0,95
Operate time, unrestrained	Typically 20ms
Reset time, unrestrained	Typically 25ms
Operate time, restrained	Typically 30ms
Reset time, restrained	Typically 25ms

Restricted earth fault protection REF (87T)

Operating characteristic	1 breakpoint
Characteristics inaccuracy	<2%
Reset ratio	0.95
Operate time	<35ms
Reset time	<25ms

Teleprotection (85)

Operate time accuracy	±5% or ±15 ms, whichever is greater

Inrush current detection function INR2, (68)

Current inaccuracy	<2 %
Reset ratio	0,95
Operating time	Approx. 20 ms

10.2 Control functions

Automatic tap changer controller

Function	Range	Accuracy
Voltage measurement	50% < U < 130%	<1%
Definite time delay		<2% or +/-20ms, whichever is greater

Inverse and “2powerN” time delay	12% < DU < 25%	<5%
	25% < DU < 50%	2% or +/- 20ms, whichever is greater

Synchroncheck function du/df (25)

Rated Voltage Un	100/200V, setting parameter
Voltage effective range	10-110 % of Un
Voltage inaccuracy	±1% of Un
Frequency effective range	47.5 – 52.5 Hz
Frequency inaccuracy	±10mHz
Phase angle inaccuracy	±3 °
Operate time inaccuracy	±3ms
Reset time	<50ms
Reset ratio	0.95

10.3 Monitoring functions

Current transformer supervision function CTS

Pick-up starting inaccuracy at In	<2%
Minimum operation time	70ms
Reset ratio	0.95

Voltage transformer supervision function VTS

Pick-up voltage inaccuracy	1 %
Operation time inaccuracy	<20 ms
Reset ratio	0.95

10.4 Hardware

Power supply module

Input voltage	80-255VAC 90-300VDC
Nominal voltage	110VDC/220VDC
Maximum interruption	100ms
Maximum power consumption	30W

Current measurement module

Nominal current	1/5A (parameter settable) 0.2A (ordering option)
Number of channels per module	4
Rated frequency	50Hz 60Hz (ordering option)
Burden	<0.1VA at rated current
Thermal withstand	20A (continuous) 500A (for 1s) 1200A (for 10ms)
Current measurement range	0-50xIn
Power consumption at rated current	0.01 VA with 1A rated current 0.25 VA with 5A rated current
Phase angle accuracy at Ix ≥ 10% ± 1 digit	≤ 0.5 º
Relative accuracy [%] ± 1 digit	± 1 (> 0.5In) with 1A rated current ± 1 (> 0.4In) with 5A rated current

Voltage measurement module

Rated voltage Un	100/√3, 100V, 200/√3, 200V (parameter settable)
Number of channels per module	4
Rated frequency	50Hz 60Hz (ordering option)
Burden	<1VA at 200V
Voltage withstand	250V (continuous) 275VAC/350VDC (1s)
Voltage measurement range	0.05-1.2xUn
Power consumption	0.61VA at 200V 0.2 VA at 100V
Relative accuracy	±0.5 % (>0.6Un)
Frequency measurement range	±0.01 % at Ux ≥ 25% of rated voltage
Phase angle accuracy	≤ 0.5 º at Ux ≥ 25% of rated voltage

Binary input module

Rated voltage Un	110 or 220Vdc (ordering option)
Number of inputs per module	12 (in groups of 3)
Current drain	approx. 2mA per channel

Breaking capacity	0.2A (L/R=40ms, 220Vdc)

Binary output module

Rated voltage Un	250Vac/dc
Number of outputs per module	7 (NO) + 1(NC)
Continuous carry	8A
Breaking capacity	0.2A (L/R=40ms, 220Vdc)

High speed trip module

Rated voltage Un	110/220VDC
Max. withstand voltage	242V DC
Number of outputs per module	4
Continuous carry	8A
Making capacity	30A (0.5s)
Breaking capacity	4A (L/R=40ms, 220Vdc)

Milliampere input module

Number of channels	4
Measurement method	2 wire inputs with optional 15V excitation
Relative accuracy	± 0.5 % ± 1 digit
Measurement ranges	± 20 mA (typical 0-20, 4-20 mA) Rload = 56 Ω

10.5 Tests and environmental conditions

Disturbance tests

EMC test	CE approved and tested according to EN 50081-2, EN 50082-2
Emission - Conducted (EN 55011 class A) - Emitted (EN 55011 class A)	0.15 - 30MHz 30 - 1 000MHz
Immunity	
- Static discharge (ESD) (According to IEC244-22-2 and EN61000-4-2, class III)	Air discharge 8kV Contact discharge 6kV
- Fast transients (EFT) (According to EN61000-4-4, class III and IEC801-4, level 4)	Power supply input 4kV, 5/50ns other inputs and outputs 4kV, 5/50ns

- Surge (According to EN61000-4-5 [09/96], level 4)	Between wires 2 kV / 1.2/50µs Between wire and earth 4 kV / 1.2/50µs
- RF electromagnetic field test (According. to EN 61000-4-3, class III)	f = 80….1000 MHz 10V /m
- Conducted RF field (According. to EN 61000-4-6, class III)	f = 150 kHz….80 MHz 10V

Voltage tests

Insulation test voltage acc- to IEC 60255-5	2 kV, 50Hz, 1min
Impulse test voltage acc- to IEC 60255-5	5 kV, 1.2/50us, 0.5J

Mechanical tests

Vibration test	2 ... 13.2 Hz ±3.5mm 13.2 ... 100Hz, ±1.0g
Shock/Bump test acc. to IEC 60255-21-2	20g, 1000 bumps/dir.

Casing and package

Protection degree (front)	IP 54 (with optional cover)
Weight	5kg net (AQ-x35x devices) 6kg net (AQ-x39x devices) 6kg with package (AQ-x35x devices) 7kg with package (AQ-x39x devices)

Environmental conditions

Specified ambient service temp. range	-10…+55°C
Transport and storage temp. range	-40…+70°C

11 Ordering information

Visit https://configurator.arcteq.fi/ to build a hardware configuration, define an ordering code and get a module layout image.

12 Contact and reference information

Manufacturer

Arcteq Relays Ltd.

Visiting and postal address

Kvartsikatu 2 A 1

65300 Vaasa, Finland

Contacts

Phone:	+358 10 3221 370
Website:	arcteq.fi
Technical support:	support.arcteq.fi +358 10 3221 388 (EET 9:00 – 17.00)
E-mail (sales):	sales@arcteq.fi